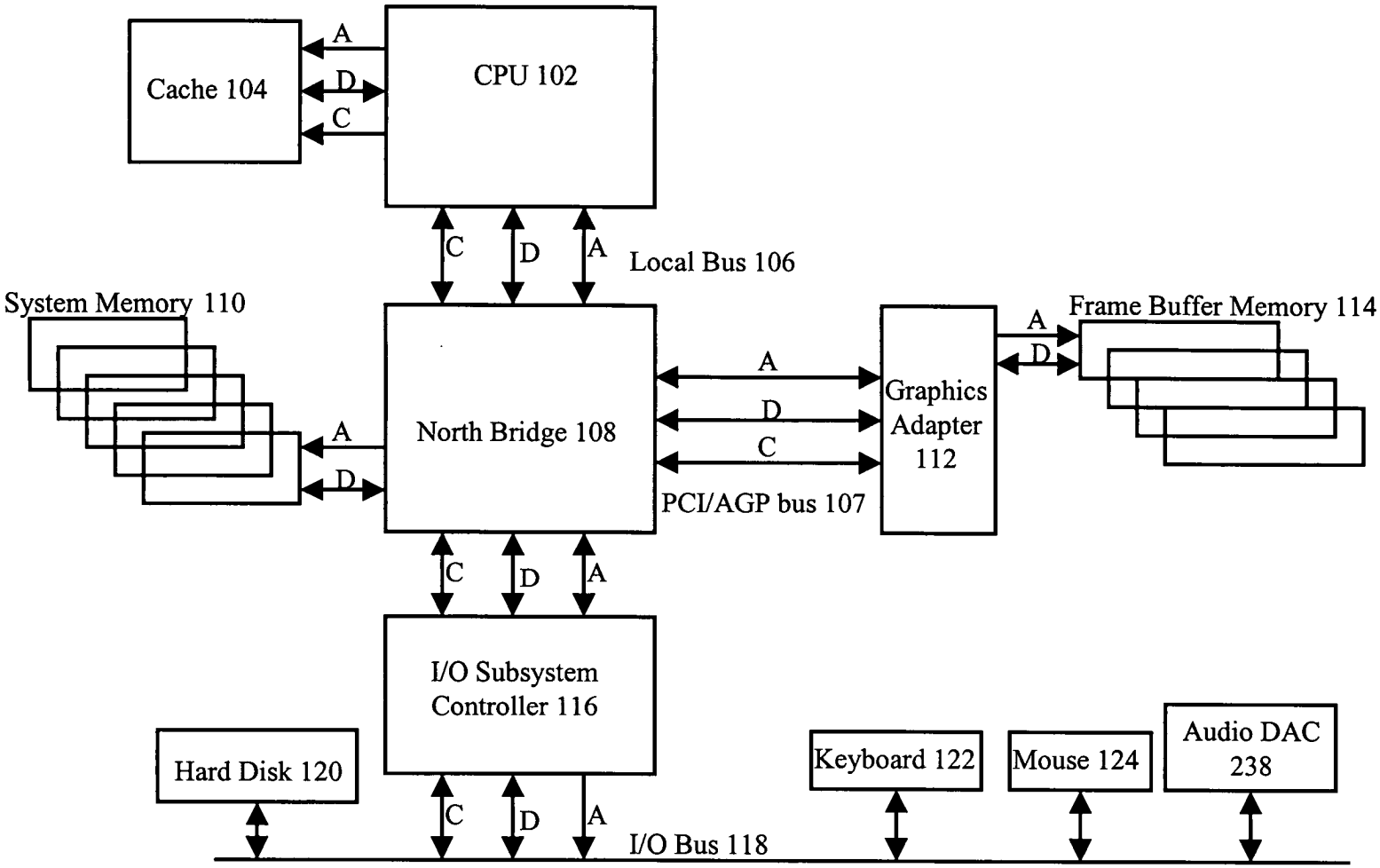


Figure 1
Prior Art

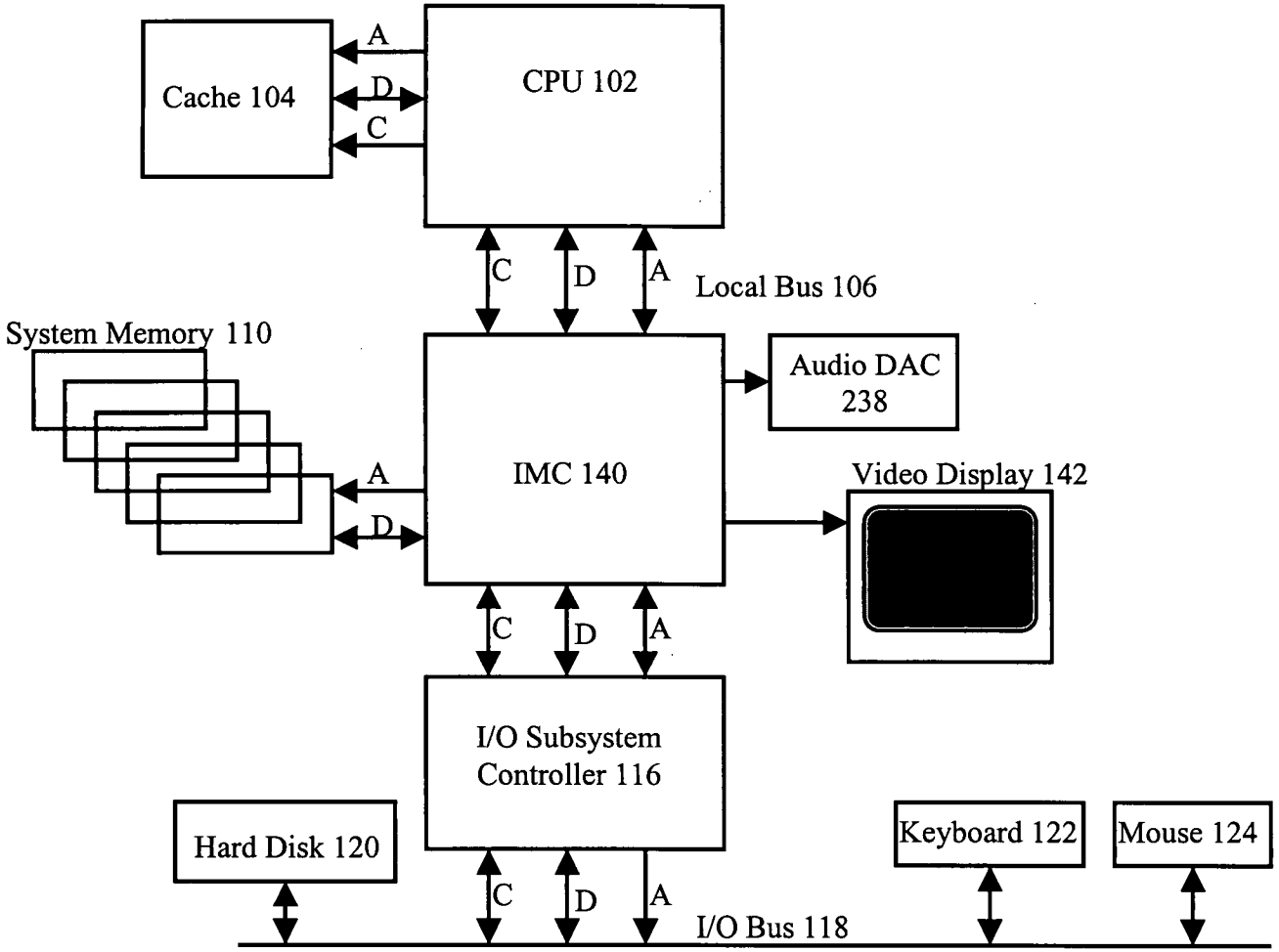

Cache 104
A
D
C
CPU 102
C
D
A
Local Bus 106
System Memory 110
Audio DAC
238
A
D
IMC 140
Video Display 142
C
D
A
I/O Subsystem
Controller 116
Hard Disk 120
Keyboard 122
Mouse 124
C
D
A
I/O Bus 118

Figure 2

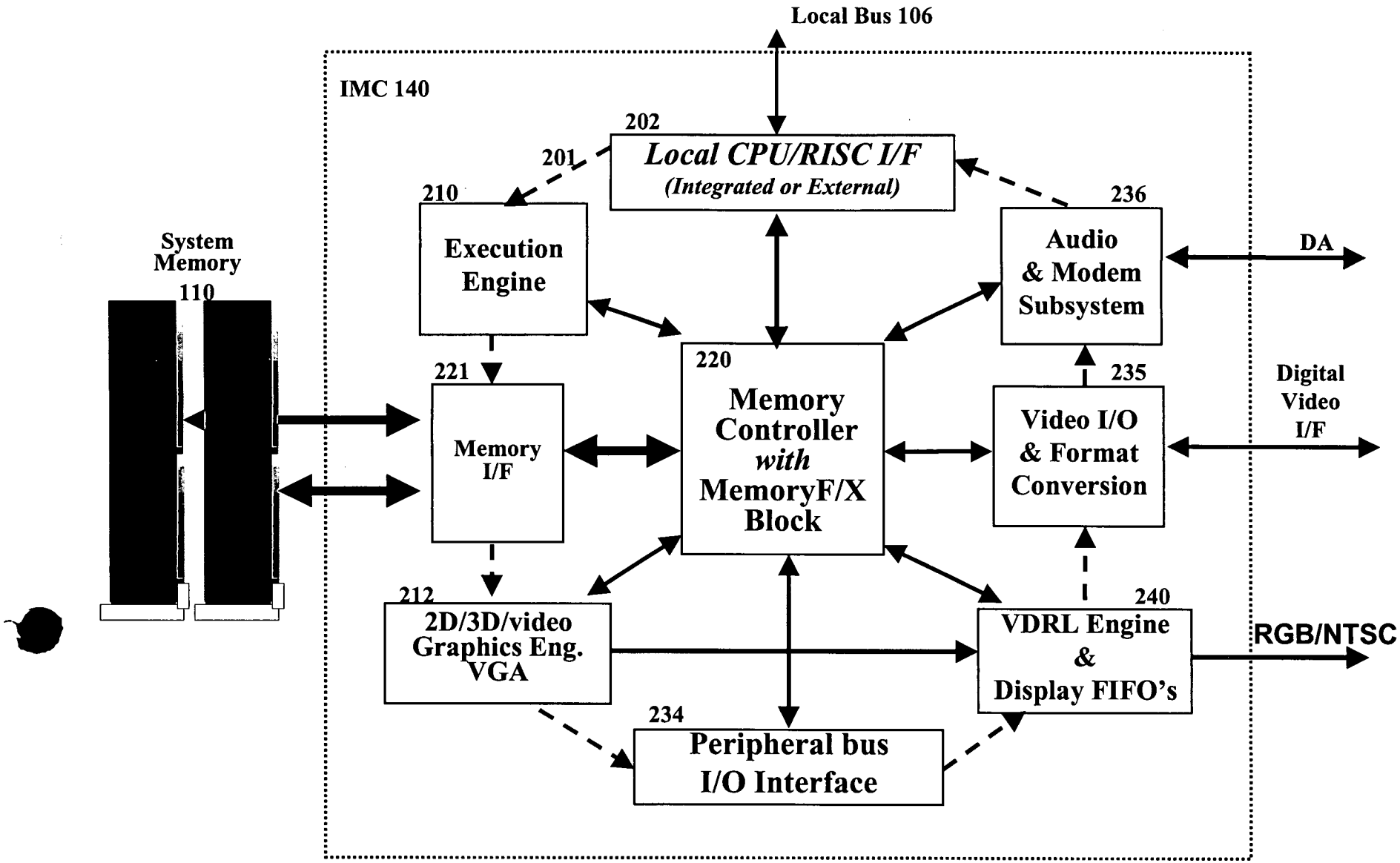

Local Bus 106
IMC 140
202
201
Local CPU/RISC I/F
(Integrated or External)
210
Execution Engine
236
Audio & Modem Subsystem
DA
System Memory
110
221
Memory I/F
220
Memory Controller with MemoryF/X Block
235
Video I/O & Format Conversion
Digital Video I/F
212
2D/3D/video Graphics Eng. VGA
240
VDRL Engine & Display FIFO's
RGB/NTSC
234
Peripheral bus I/O Interface

Figure 3

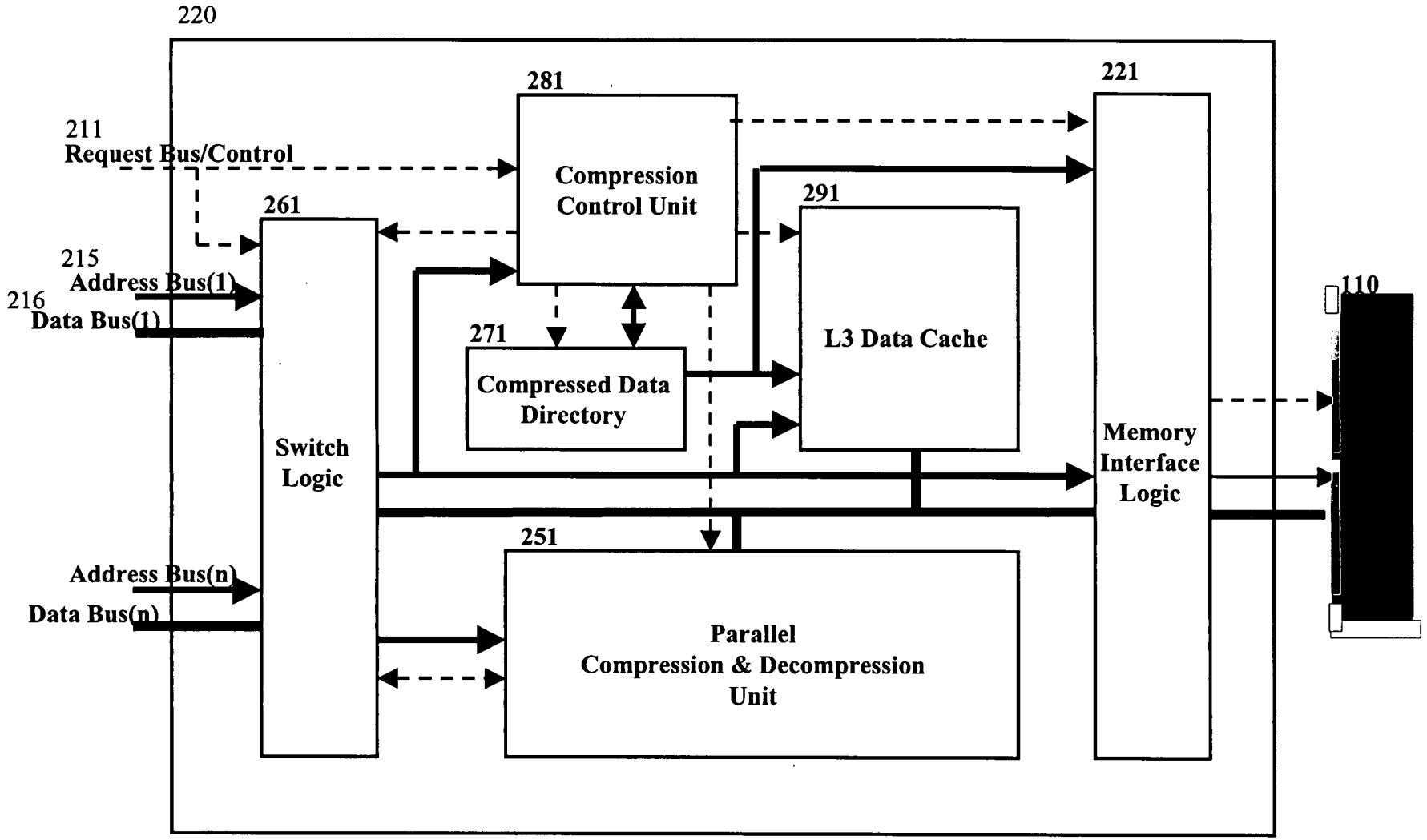
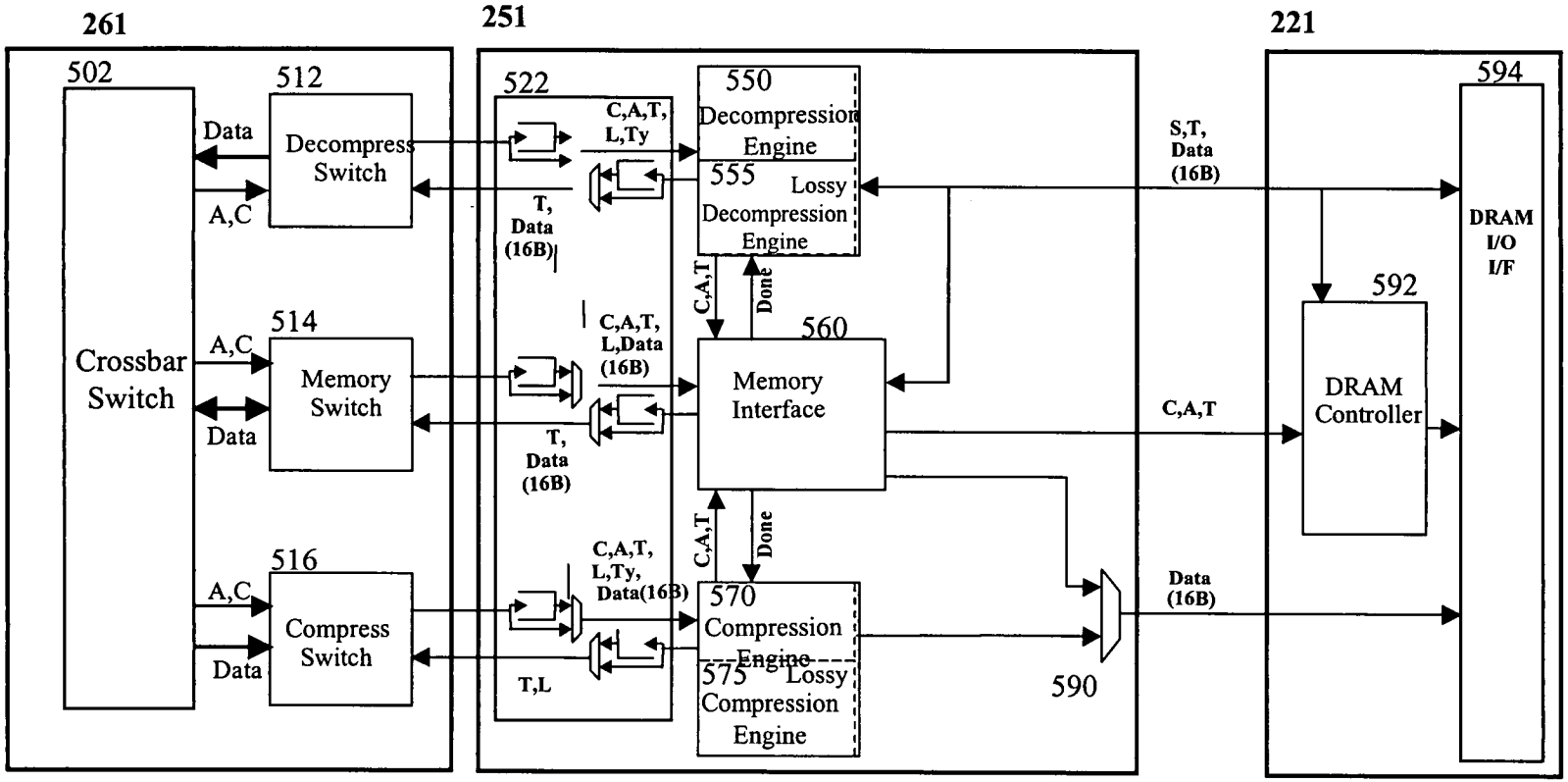


Figure 4

0923659 .012999



Key:
C – Command
A – Address
T – Tag
L – Length
Ty – Type
S – Status

Figure 5

0923959 .012959

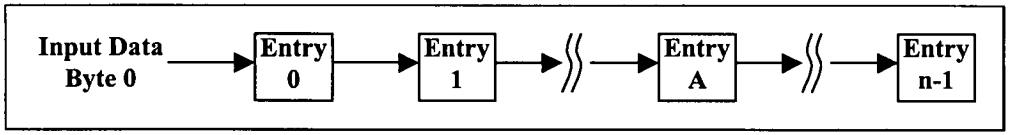


Figure 6A, Prior Art

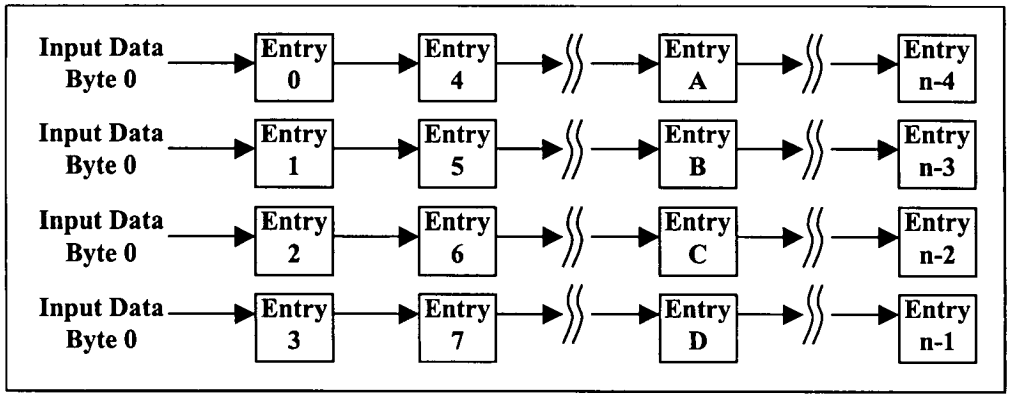


Figure 6B, New Art

09239659 .012999

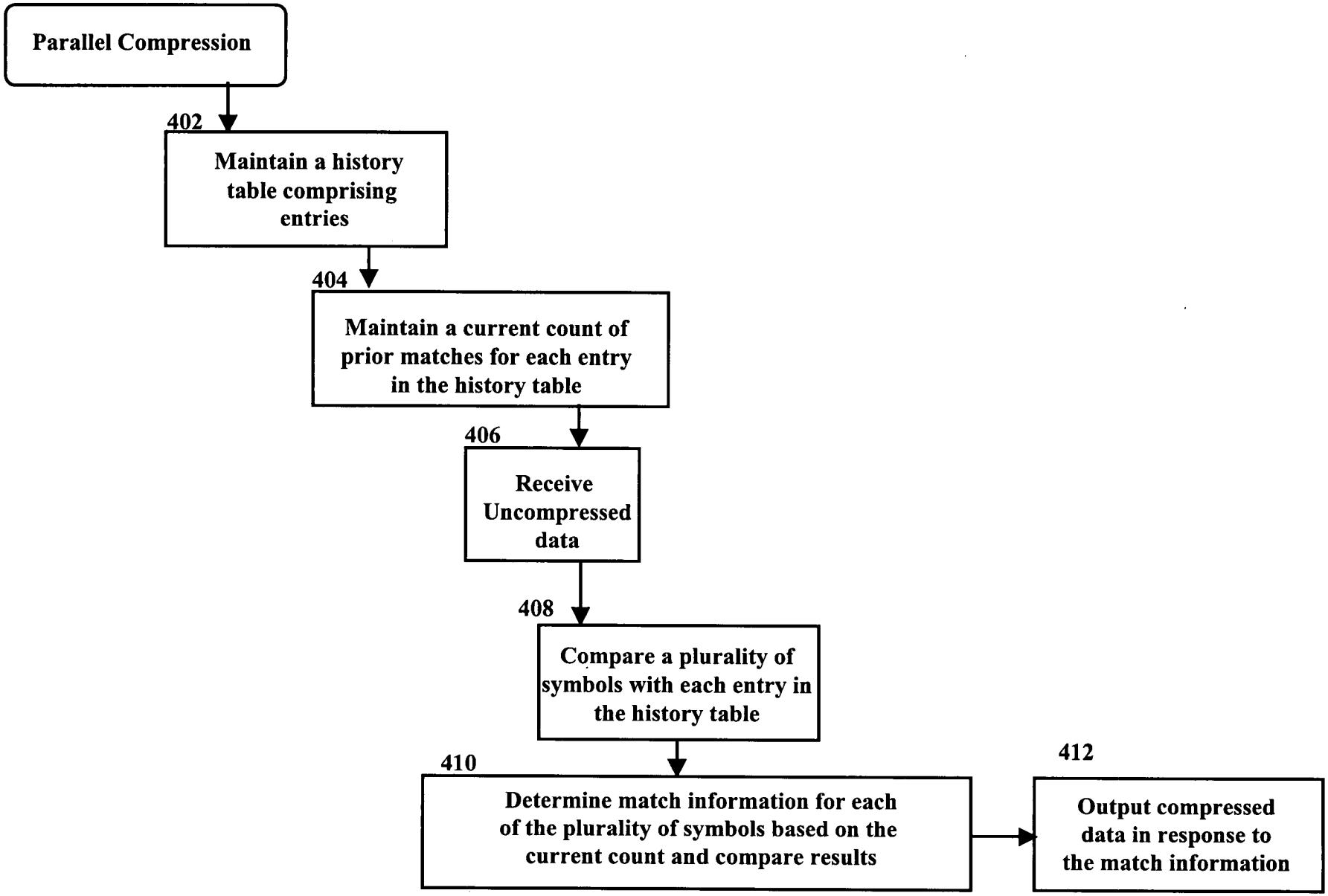


Figure 7

09239659 .012999

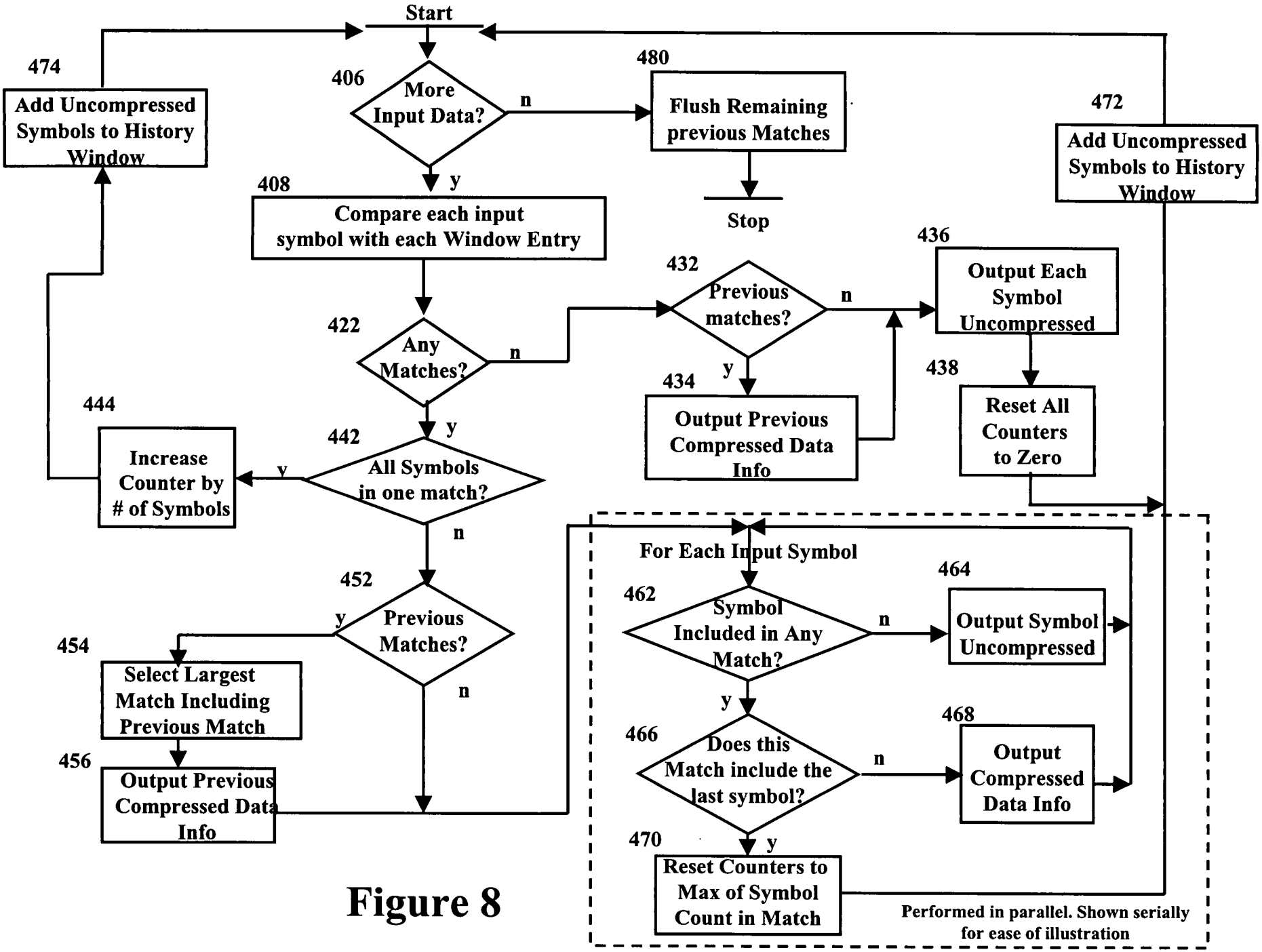


Figure 8

09239659.012599

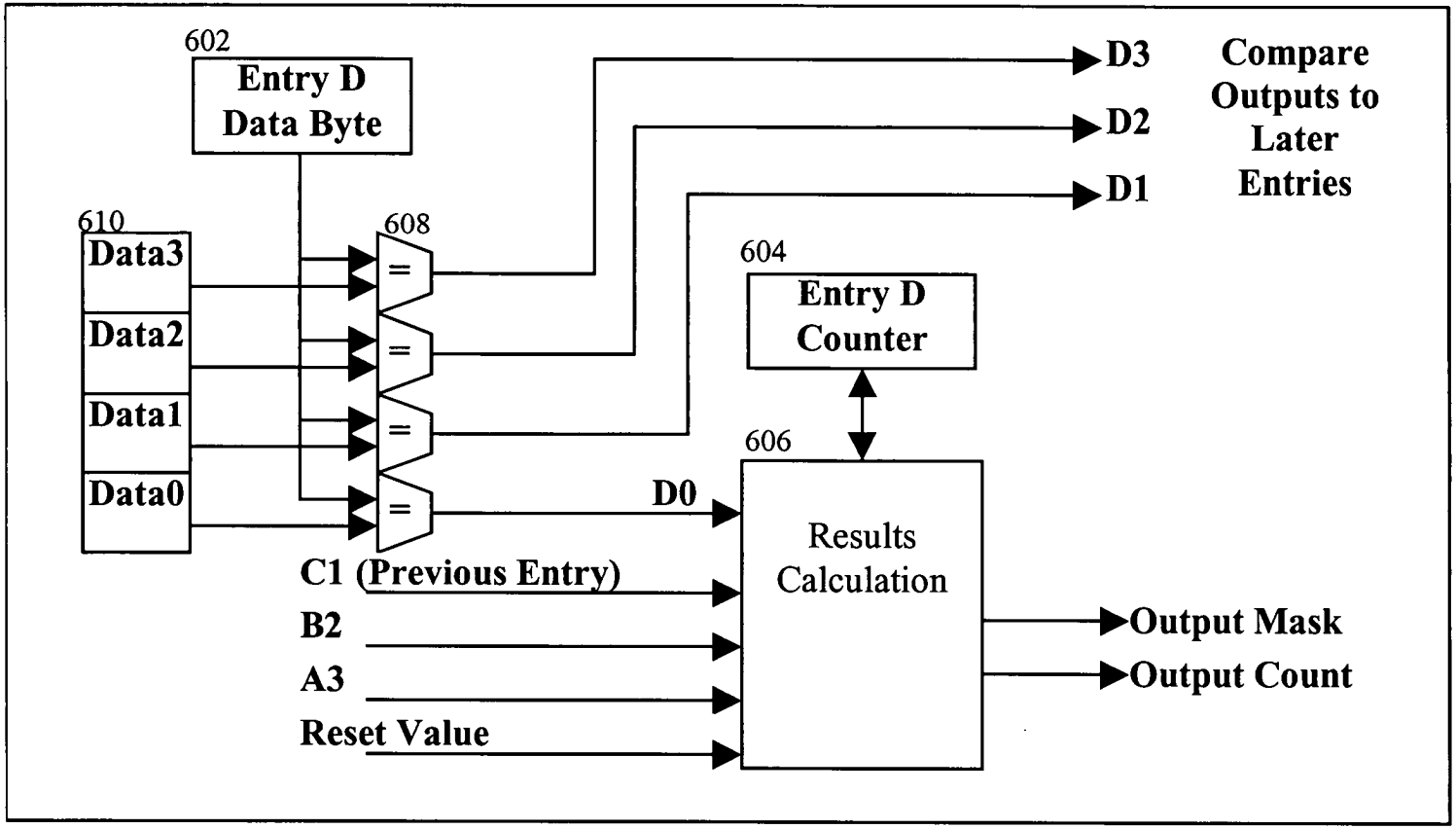


Figure 9

09239659 .012999

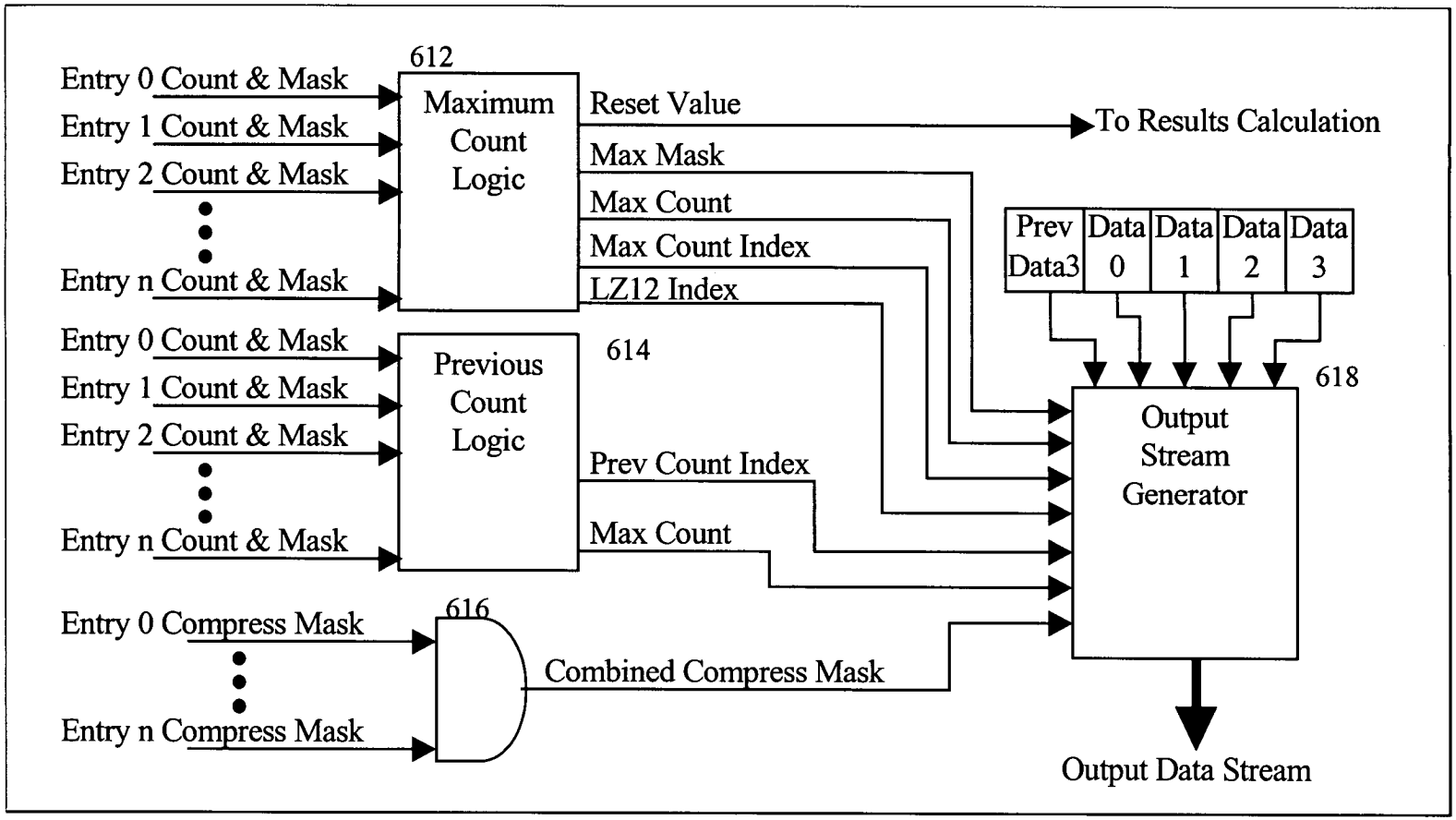


Figure 10

09239659 .012595

Input Matches				New Counter Value	Output Counter	Output Mask	Reset Value
D0	C1	B2	A3				
1	1	1	1	Saved+4	Saved +4	10000	0
1	1	1	0	0	Saved+3	10001	1
1	1	0	1	1	Saved+2	10010	2
1	1	0	0	0	Saved+2	10011	2
1	0	1	1	2	Saved+1	10100	3
1	0	1	0	0	Saved+1	10101	3
1	0	0	1	1	Saved+1	10110	3
1	0	0	0	0	Saved+1	10111	3
0	1	1	1	3	Saved	11000	4
0	1	1	0	0	Saved	01111	1
0	1	0	1	1	Saved	11010	4
0	1	0	0	0	Saved	11011	4
0	0	1	1	2	Saved	11100	4
0	0	1	0	0	Saved	11101	4
0	0	0	1	1	Saved	11110	4
0	0	0	0	0	Saved	11111	4

Figure 11

09239659 .012399

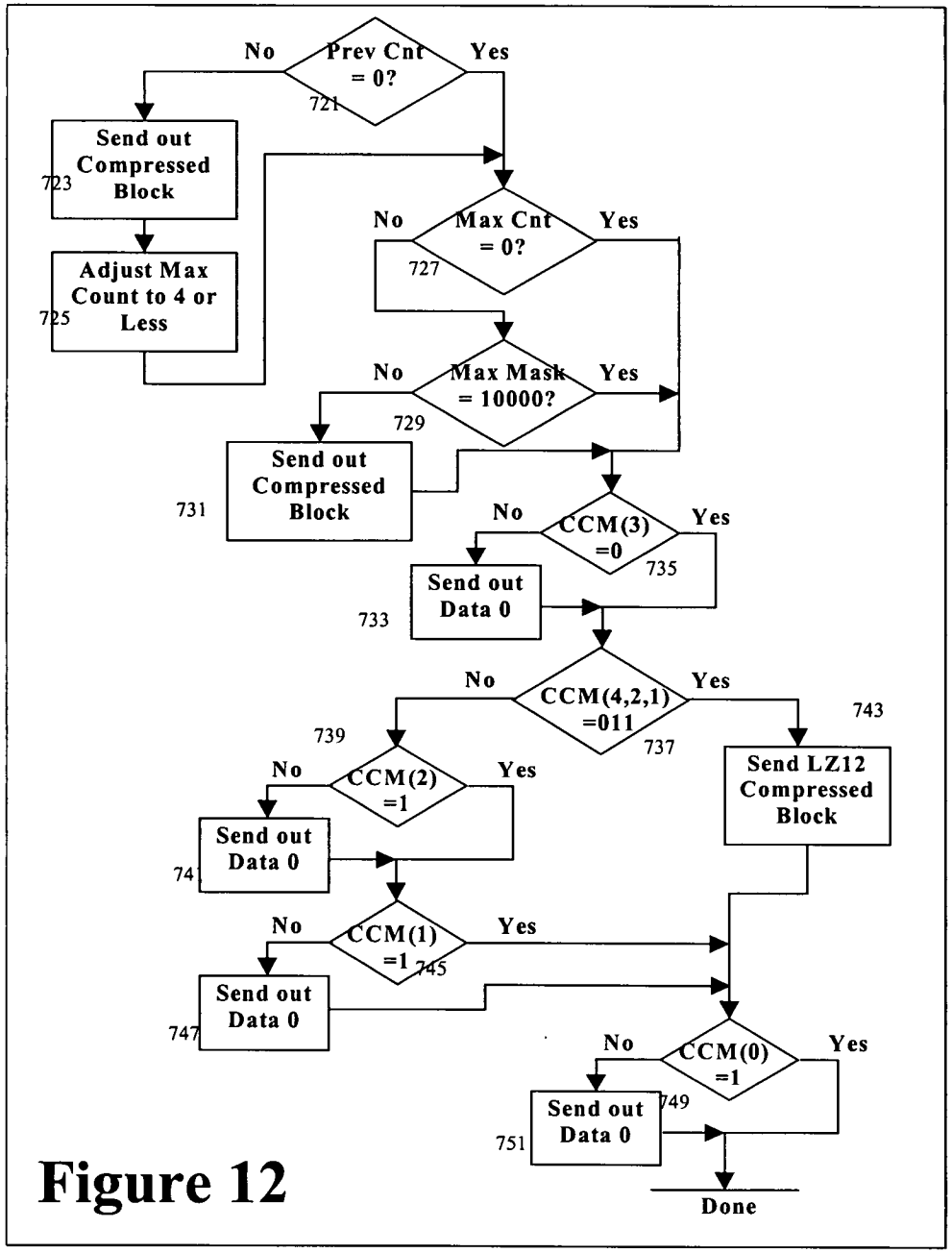


Figure 12

09239659 .012599

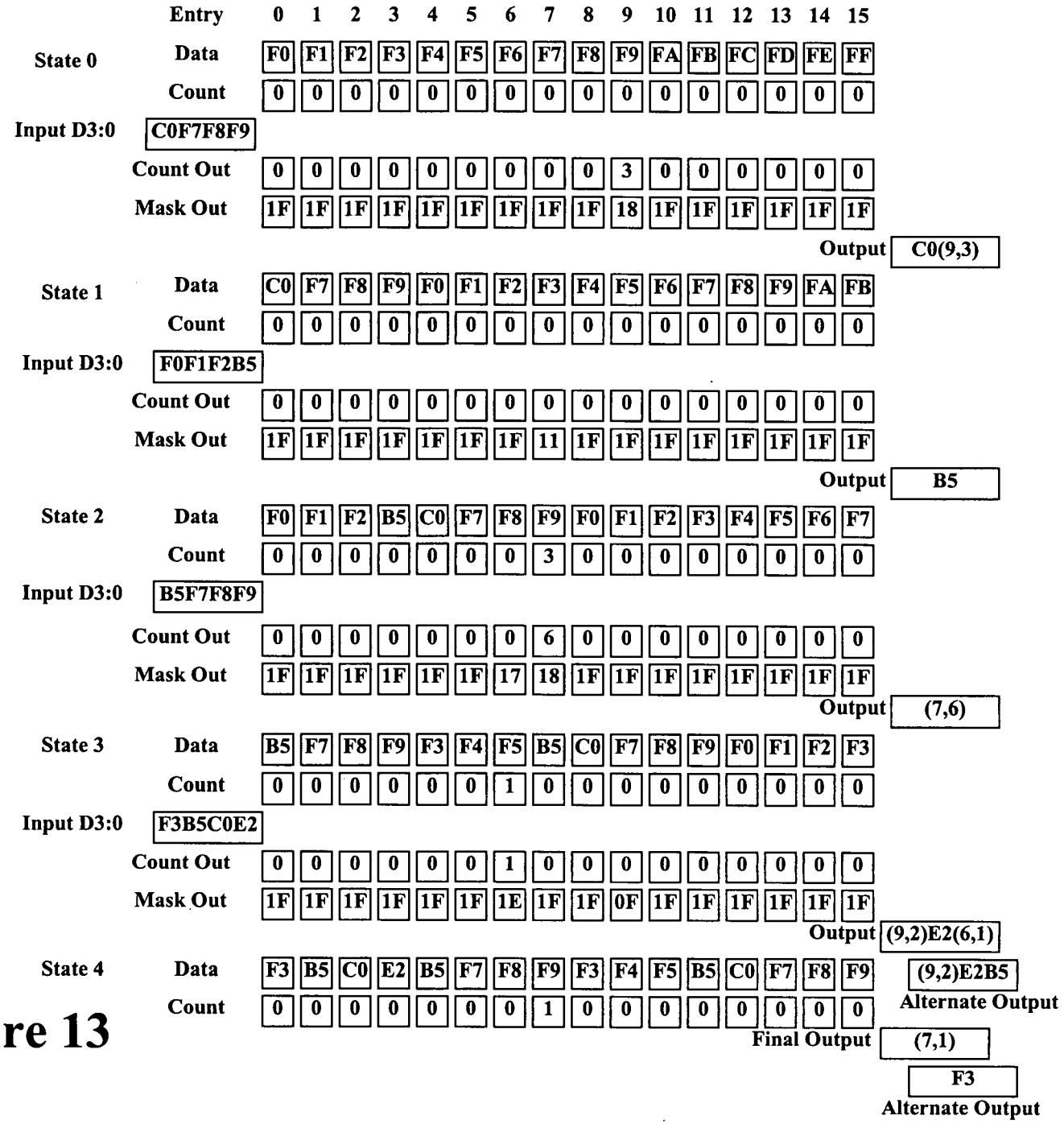

Entry 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
State 0
Data F0 F1 F2 F3 F4 F5 F6 F7 F8 F9 FA FB FC FD FE FF
Count 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Input D3:0 C0F7F8F9
Count Out 0 0 0 0 0 0 0 0 0 3 0 0 0 0 0 0
Mask Out 1F 1F 1F 1F 1F 1F 1F 1F 1F 18 1F 1F 1F 1F 1F 1F
Output C0(9,3)
State 1
Data C0 F7 F8 F9 F0 F1 F2 F3 F4 F5 F6 F7 F8 F9 FA FB
Count 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Input D3:0 F0F1F2B5
Count Out 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Mask Out 1F 1F 1F 1F 1F 1F 1F 11 1F 1F 1F 1F 1F 1F 1F 1F
Output B5
State 2
Data F0 F1 F2 B5 C0 F7 F8 F9 F0 F1 F2 F3 F4 F5 F6 F7
Count 0 0 0 0 0 0 0 3 0 0 0 0 0 0 0 0
Input D3:0 B5F7F8F9
Count Out 0 0 0 0 0 0 0 6 0 0 0 0 0 0 0 0
Mask Out 1F 1F 1F 1F 1F 1F 17 18 1F 1F 1F 1F 1F 1F 1F 1F
Output (7,6)
State 3
Data B5 F7 F8 F9 F3 F4 F5 B5 C0 F7 F8 F9 F0 F1 F2 F3
Count 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0
Input D3:0 F3B5C0E2
Count Out 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0
Mask Out 1F 1F 1F 1F 1F 1F 1E 1F 1F 0F 1F 1F 1F 1F 1F 1F
Output (9,2)E2(6,1)
State 4
Data F3 B5 C0 E2 B5 F7 F8 F9 F3 F4 F5 B5 C0 F7 F8 F9
(9,2)E2B5
Alternate Output
Count 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0
Final Output (7,1)
F3
Alternate Output

Figure 13

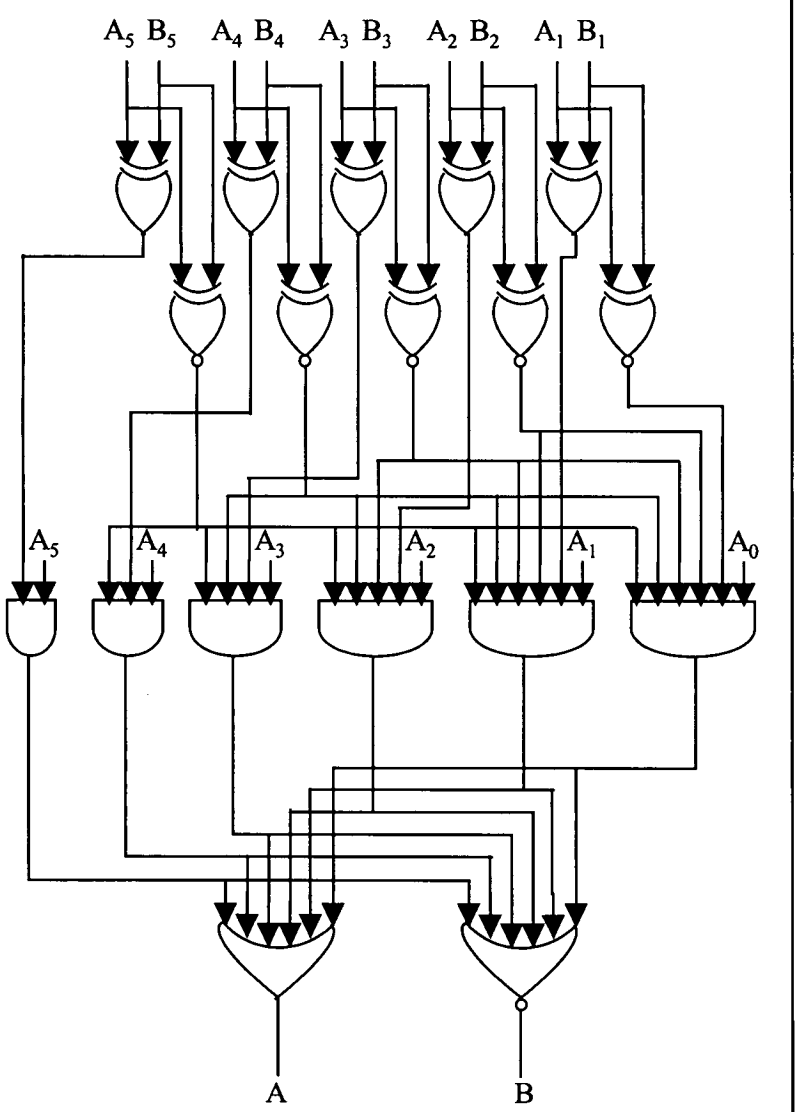


Figure 14

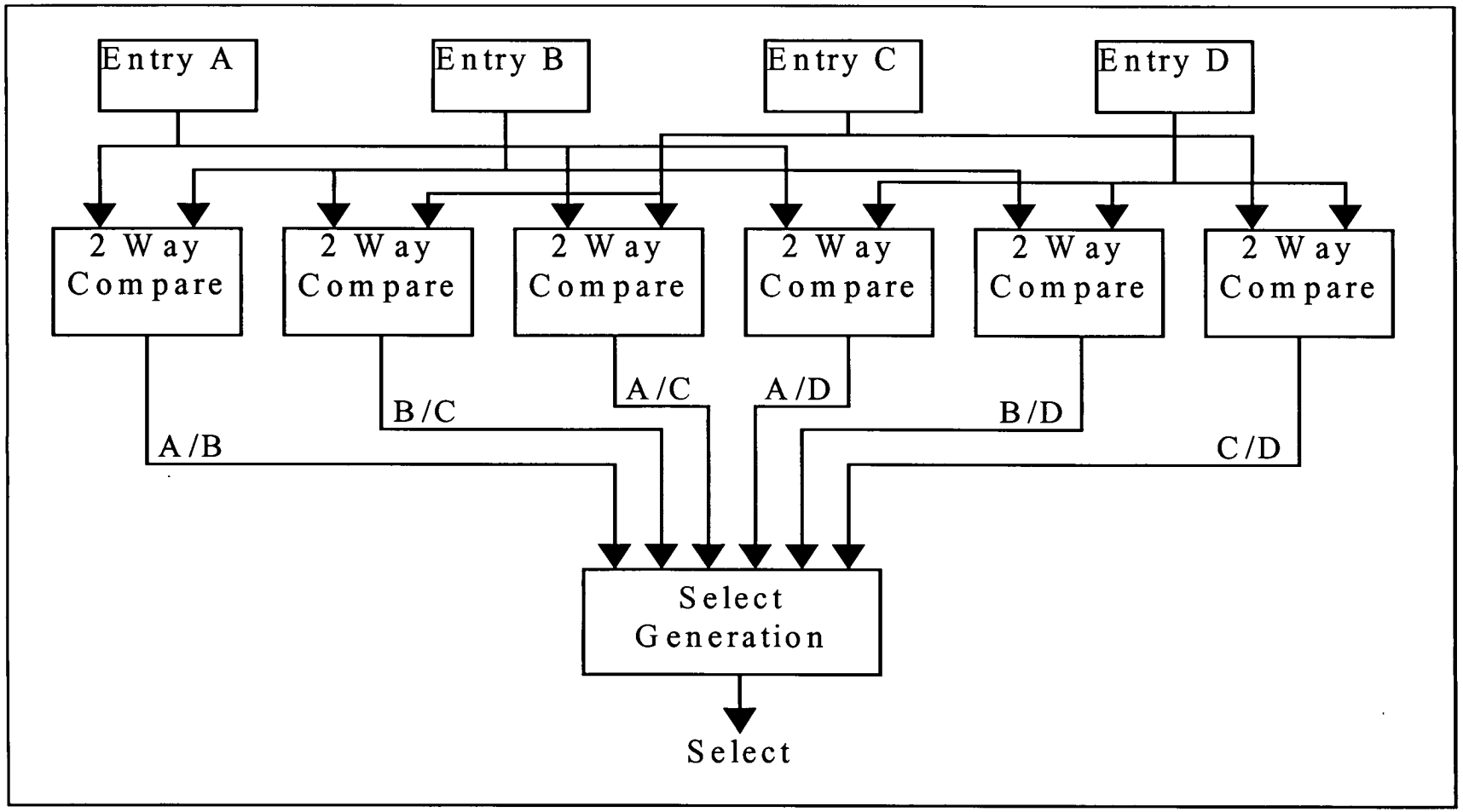

Entry A
Entry B
Entry C
Entry D
2 Way Compare
2 Way Compare
2 Way Compare
2 Way Compare
2 Way Compare
2 Way Compare
A/B
B/C
A/C
A/D
B/D
C/D
Select Generation
Select

Figure 15

A/ B	B/ C	C/ D	D/ A	A/ C	B/ D	Output
0	X	X	1	0	X	A
1	0	X	X	X	0	B
X	1	0	X	1	X	C
X	X	1	0	X	1	D

Figure 16

09253659 .012995

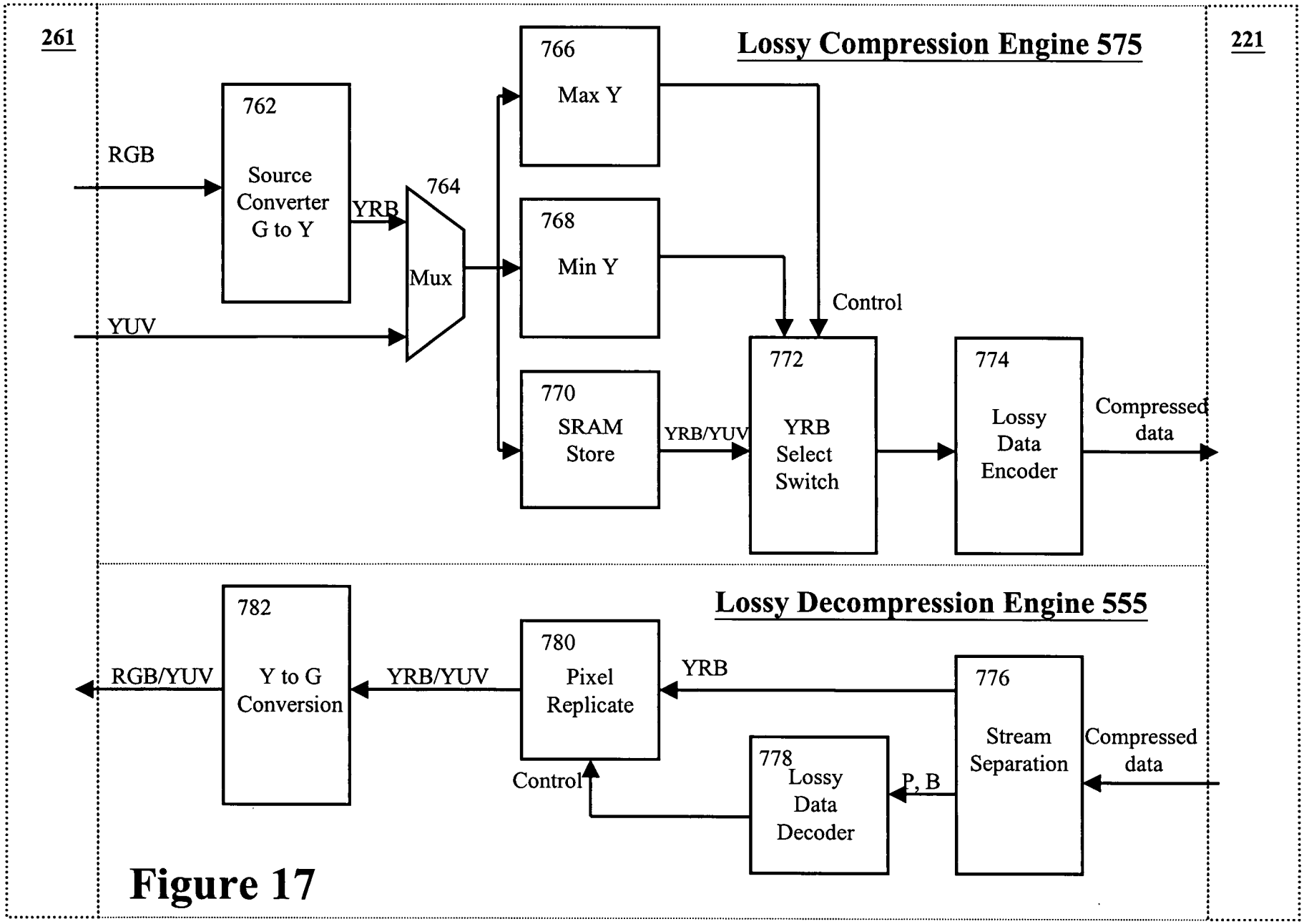

261
221
Lossy Compression Engine 575
766
Max Y
762
RGB
Source
Converter
G to Y
YRB
764
Mux
768
Min Y
YUV
Control
772
YRB
Select
Switch
770
SRAM
Store
YRB/YUV
774
Lossy
Data
Encoder
Compressed
data
Lossy Decompression Engine 555
782
RGB/YUV
Y to G
Conversion
YRB/YUV
780
Pixel
Replicate
YRB
776
Stream
Separation
Compressed
data
778
Lossy
Data
Decoder
P, B
Control

Figure 17

Ymax = Ymin	1 color	Ymax	Ymax	Rmax	Bmax	11			3 Bytes
		6 bits	6 bits	5 bits	5 bits	2 bits			
Ymax != Ymin	2 colors	Ymax	Ymin	Rmax	Rmin	Bmax	Bmin	P bits	6 Bytes
		6 bits	6 bits	5 bits	5 bits	5 bits	5 bits	16 bits	
Ymax != Ymin	>2 colors	Ymin	Ymax	Rmax	Rmin	Bmax	Bmin	P bits	8 Bytes
		6 bits	6 bits	5 bits	5 bits	5 bits	5 bits	32 bits	

Figure 18

Ymax = Ymin	Amax = Amin = 0x00	1 color	Ymax	Ymax	Rmax	Bmax	00					3 Bytes
			6 bits	6 bits	5 bits	5 bits	2 bits					
Ymax = Ymin	Amax = Amin = 0xFF	1 color	Ymax	Ymax	Rmax	Bmax	11					3 Bytes
			6 bits	6 bits	5 bits	5 bits	2 bits					
Ymax = Ymin	Amax = Amin != 00 or FF	1 color	Ymax	Ymax	Rmax	Bmax	01	Amax	Amin			4/5 Bytes
			6 bits	6 bits	5 bits	5 bits	2 bits	4/8 bits	4/8 bits			
Ymax = Ymin	Amax != Amin	1 color	Ymax	Ymax	Rmax	Bmax	01	Amax	Amin	P bits		6/7 Bytes
		2 Alphas	6 bits	6 bits	5 bits	5 bits	2 bits	4/8 bits	4/8 bits	16 bits		
Ymax = Ymin	Amax != Amin	1 color	Ymax	Ymax	Rmax	Bmax	10	Amax	Amin	P bits		8/9 Bytes
		>2 Alphas	6 bits	6 bits	5 bits	5 bits	2 bits	4/8 bits	4/8 bits	32 bits		
Ymax != Ymin	X	2 colors	Ymax	Ymin	Rmax	Rmin	Bmax	Bmin	Amax	Amin	P bits	7/8 Bytes
			6 bits	6 bits	5 bits	5 bits	5 bits	5 bits	4/8 bits	4/8 bits	16 bits	
Ymax != Ymin	X	>2 colors	Ymin	Ymax	Rmax	Rmin	Bmax	Bmin	Amax	Amin	P bits	9/10 Bytes
			6 bits	6 bits	5 bits	5 bits	5 bits	5 bits	4/8 bits	4/8 bits	32 bits	

Figure 19

5,923,338 - 5/1999

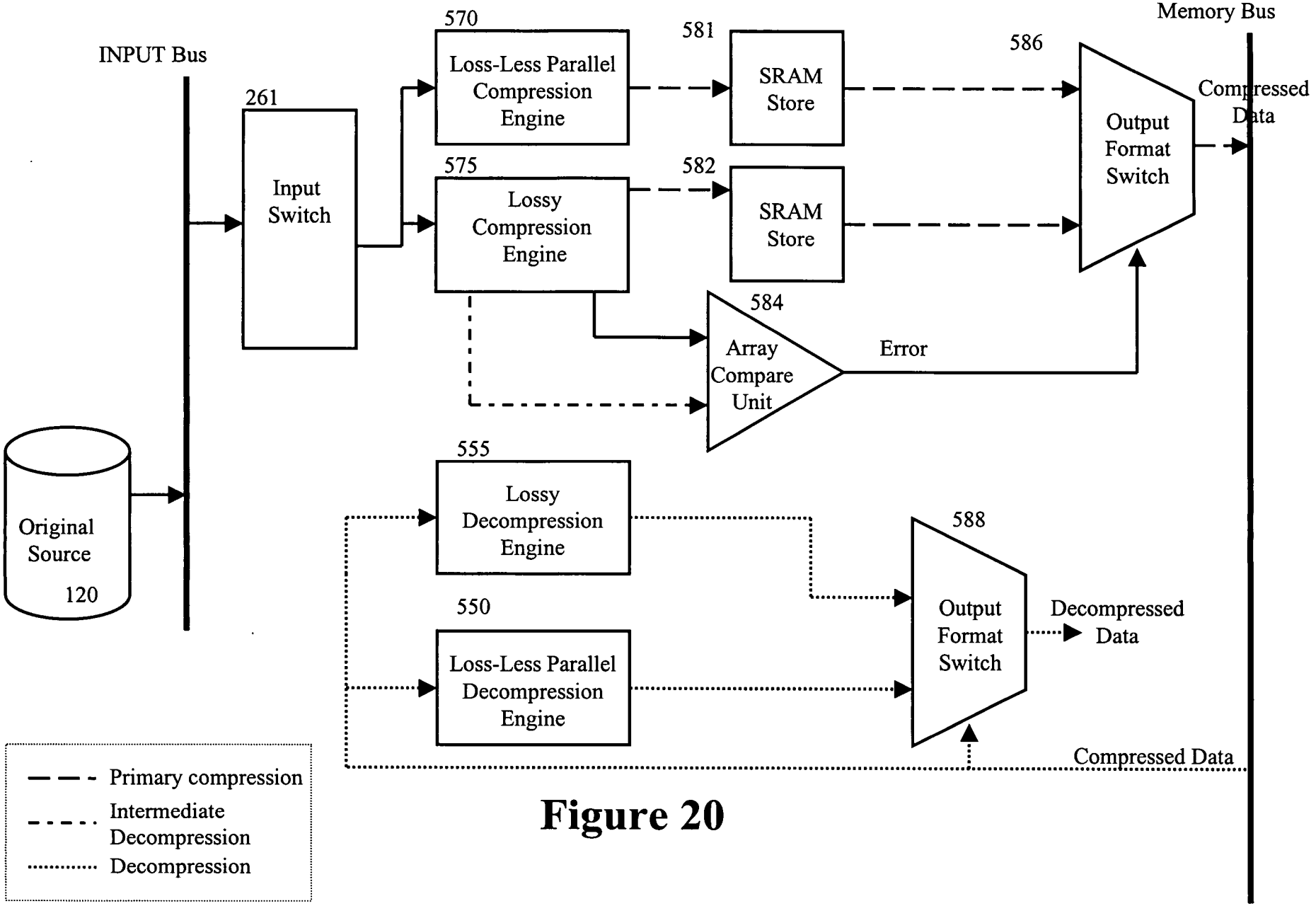

INPUT Bus
261
Input Switch
570
Loss-Less Parallel Compression Engine
575
Lossy Compression Engine
581
SRAM Store
582
SRAM Store
586
Output Format Switch
Memory Bus
Compressed Data
584
Array Compare Unit
Error
Original Source
120
555
Lossy Decompression Engine
550
Loss-Less Parallel Decompression Engine
588
Output Format Switch
Decompressed Data
Compressed Data
Primary compression
Intermediate Decompression
Decompression

Figure 20

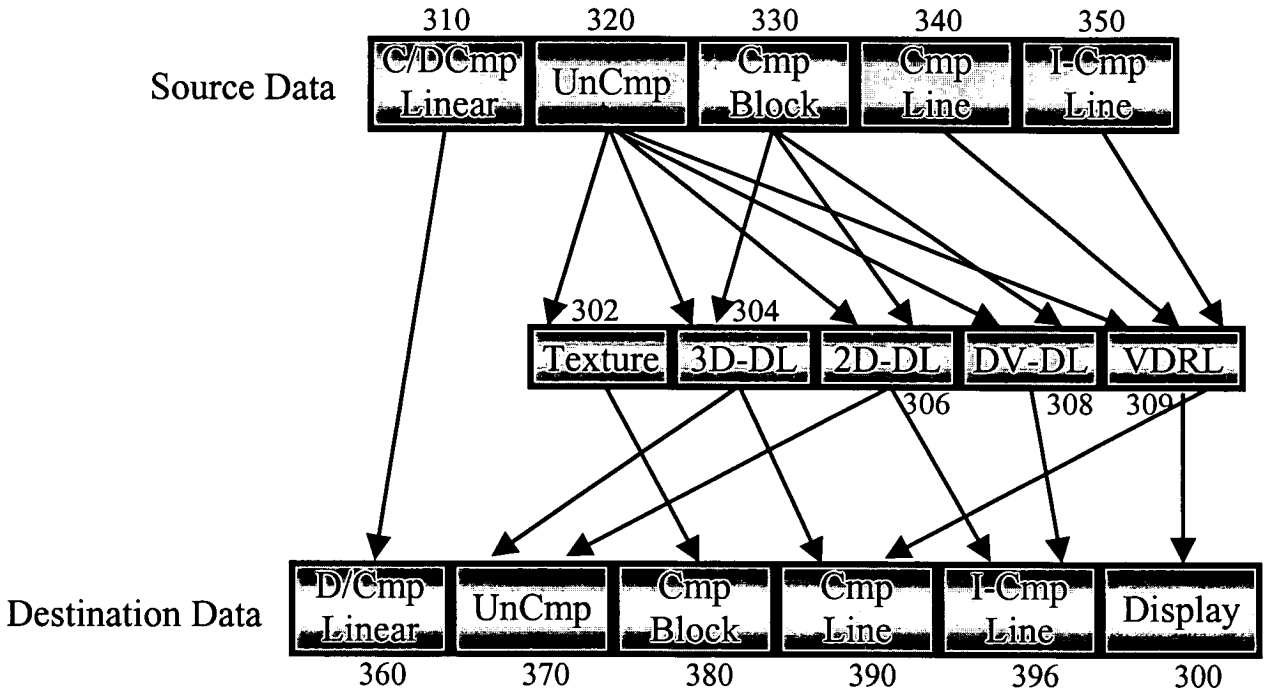

310
320
330
340
350
Source Data
C/DCmp Linear
UnCmp
Cmp Block
Cmp Line
I-Cmp Line
302
304
Texture
3D-DL
2D-DL
DV-DL
VDRL
306
308
309
Destination Data
D/Cmp Linear
UnCmp
Cmp Block
Cmp Line
I-Cmp Line
Display
360
370
380
390
396
300

Figure 21

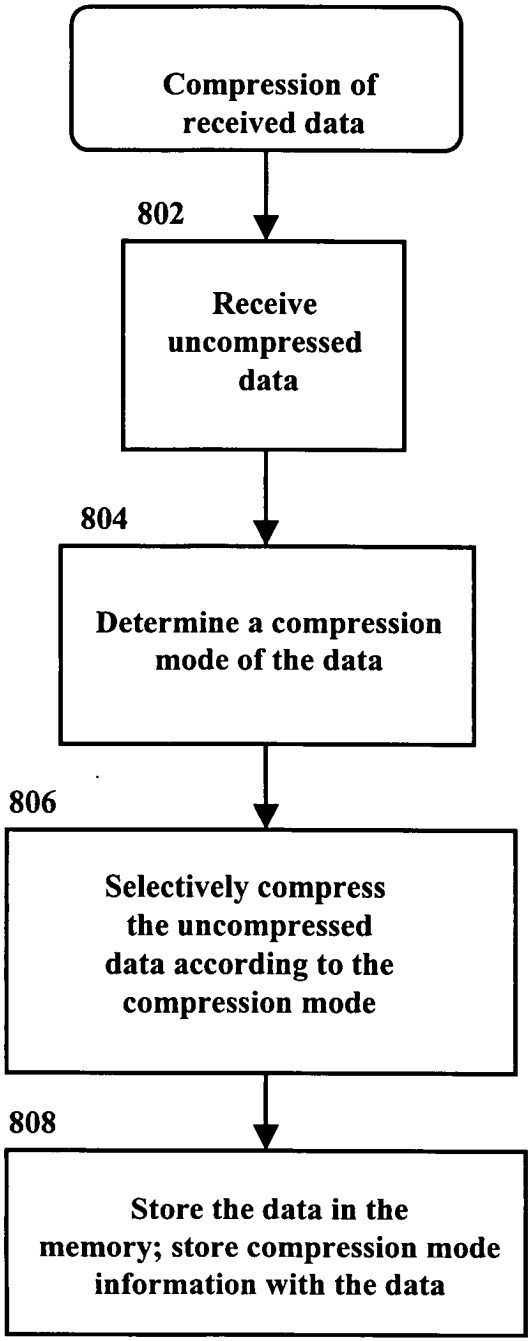

Compression of received data
802
Receive uncompressed data
804
Determine a compression mode of the data
806
Selectively compress the uncompressed data according to the compression mode
808
Store the data in the memory; store compression mode information with the data

Figure 22

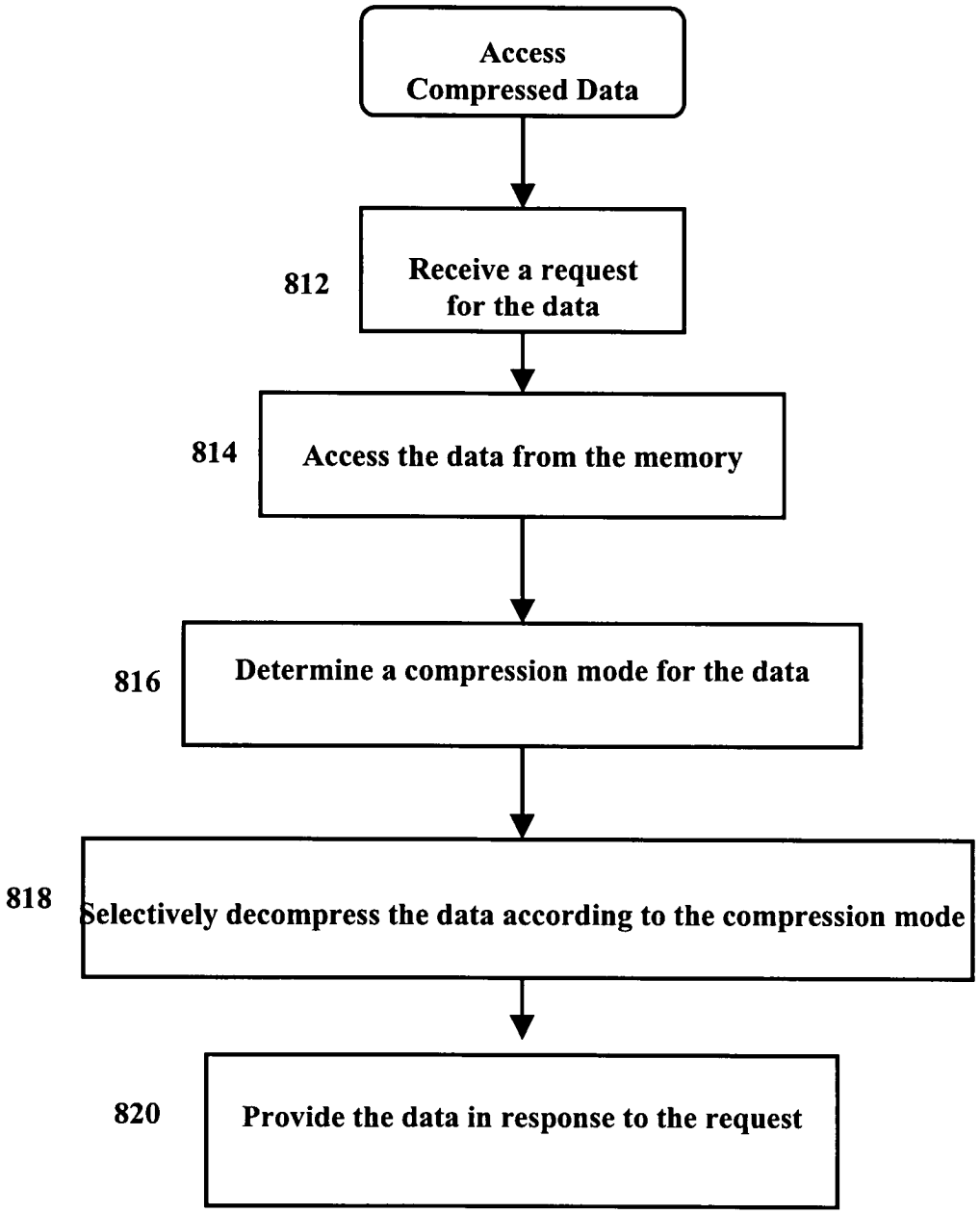

Access Compressed Data
812
Receive a request for the data
814
Access the data from the memory
816
Determine a compression mode for the data
818
Selectively decompress the data according to the compression mode
820
Provide the data in response to the request

Figure 23

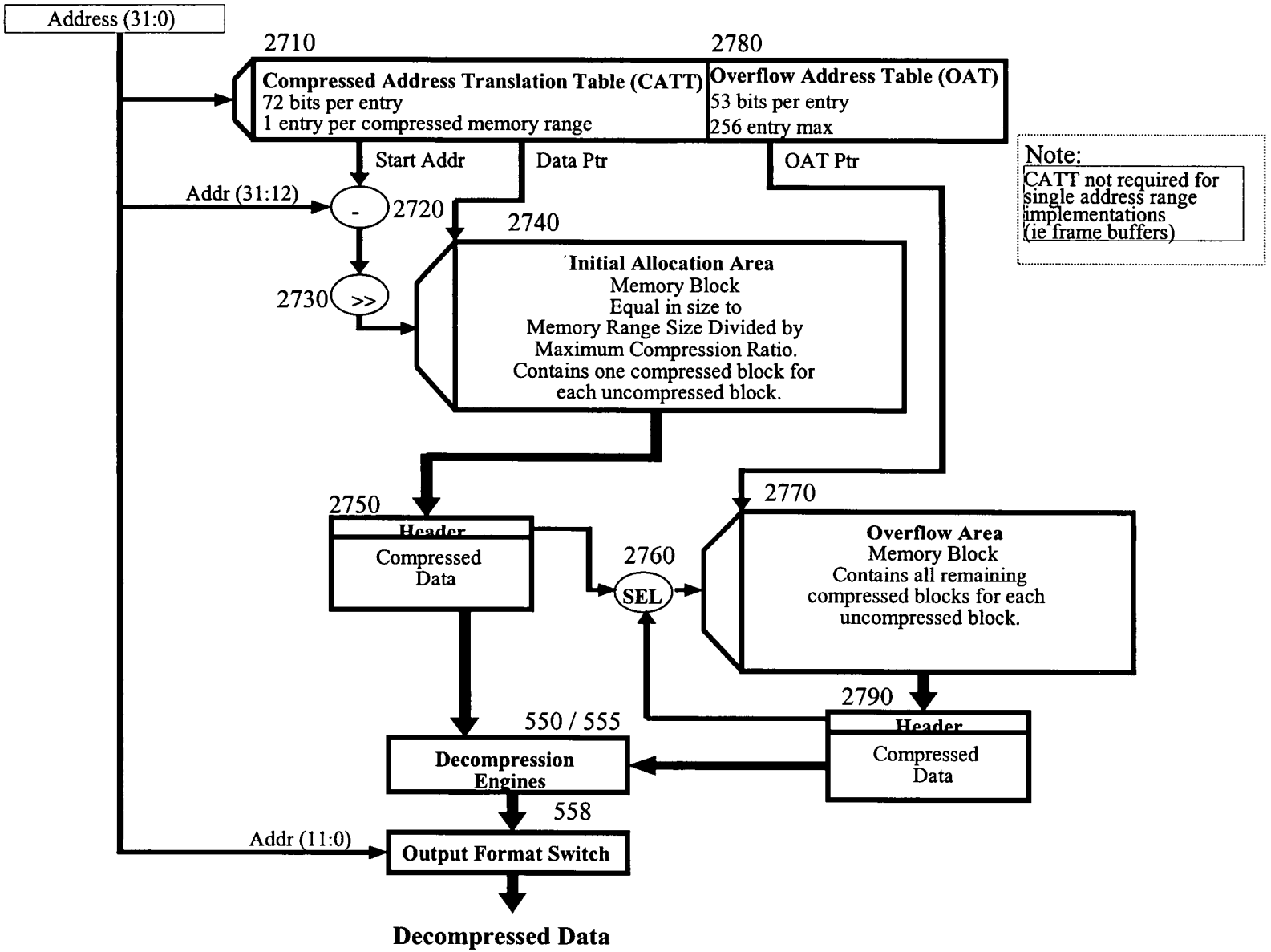

Address (31:0)
2710
Compressed Address Translation Table (CATT)
72 bits per entry
1 entry per compressed memory range
2780
Overflow Address Table (OAT)
53 bits per entry
256 entry max
Start Addr
Data Ptr
OAT Ptr
Note:
CATT not required for single address range implementations (ie frame buffers)
Addr (31:12)
-
2720
2740
2730
>>
Initial Allocation Area
Memory Block
Equal in size to
Memory Range Size Divided by
Maximum Compression Ratio.
Contains one compressed block for each uncompressed block.
2750
Header
Compressed Data
2760
SEL
2770
Overflow Area
Memory Block
Contains all remaining compressed blocks for each uncompressed block.
2790
Header
Compressed Data
550 / 555
Decompression Engines
558
Addr (11:0)
Output Format Switch
Decompressed Data

Figure 24

Compressed Address Translation Table (CATT) – 128 Entry Design Limit				
Starting Addr	Ending Addr	Type	Data Ptr	OAT Ptr
20 bits	20 bits	4 bits	20 bits	8 bits
4GB Addressability		Compressed		
4K Boundry	4K Boundry	Blk Size	4K Boundry	4K Boundry

Overflow Address Table (OAT) – 256 Entry Max			
Overflow Ptr	Next Block Ptr	Next OAT Ptr	Next OAT Valid
20 bits	24 bits	8 bits	1 bit
4 GB Addressability		Points to next entry	
4K Boundry		in this table	

Initial Header Description		
Value	# of bits	Meaning
0	1	Last Block/Unused
10 A (20 bits)	22	The next block is at offset A in the Overflow Area
11 IA(8+20 bits)	30	The next block is at offset A in the Overflow Area of OAT entry I

Overflow Header Description		
Value	# of bits	Meaning
00	2	Last Block/Unused
01	2	The next block follows physically after this one
10A (8 bits)	10	The next block is A blocks before this one (or after?)
110A (20 bits)	23	The next block is at offset A in the Overflow Area
111 IA (8+20 bits)	31	The next block is at offset A in the Overflow Area of OAT entry I

Figure 25 - Memory Allocation Fields

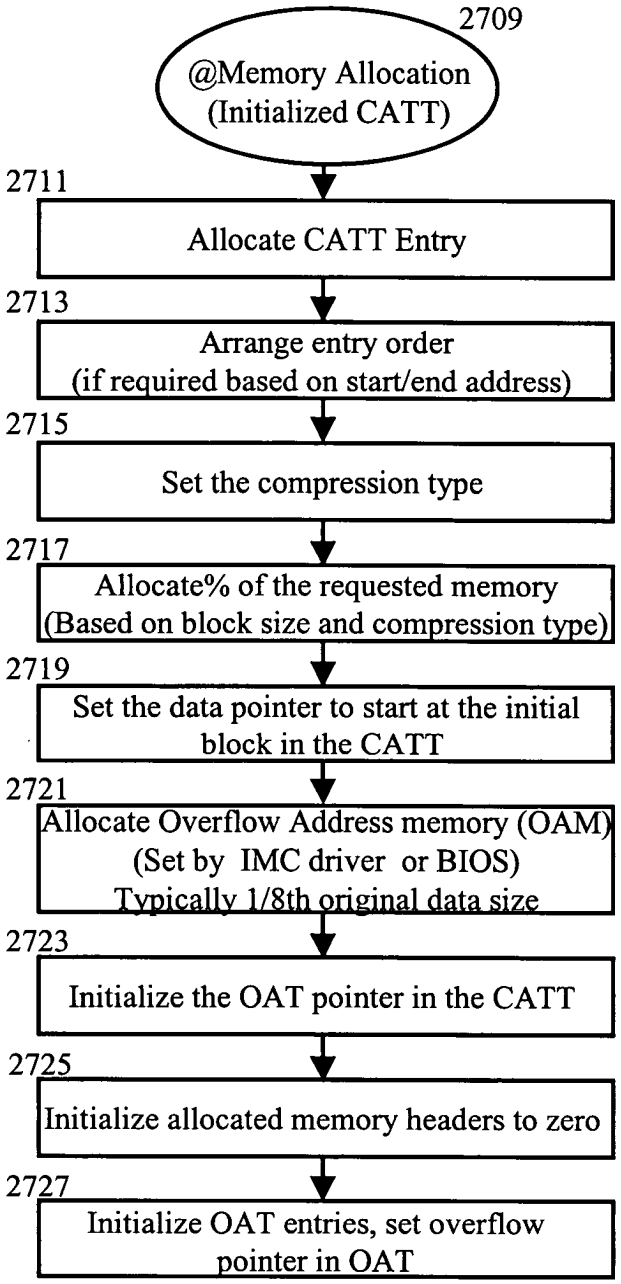

2709
@Memory Allocation
(Initialized CATT)
2711
Allocate CATT Entry
2713
Arrange entry order
(if required based on start/end address)
2715
Set the compression type
2717
Allocate% of the requested memory
(Based on block size and compression type)
2719
Set the data pointer to start at the initial
block in the CATT
2721
Allocate Overflow Address memory (OAM)
(Set by IMC driver or BIOS)
Typically 1/8th original data size
2723
Initialize the OAT pointer in the CATT
2725
Initialize allocated memory headers to zero
2727
Initialize OAT entries, set overflow
pointer in OAT

Figure 26

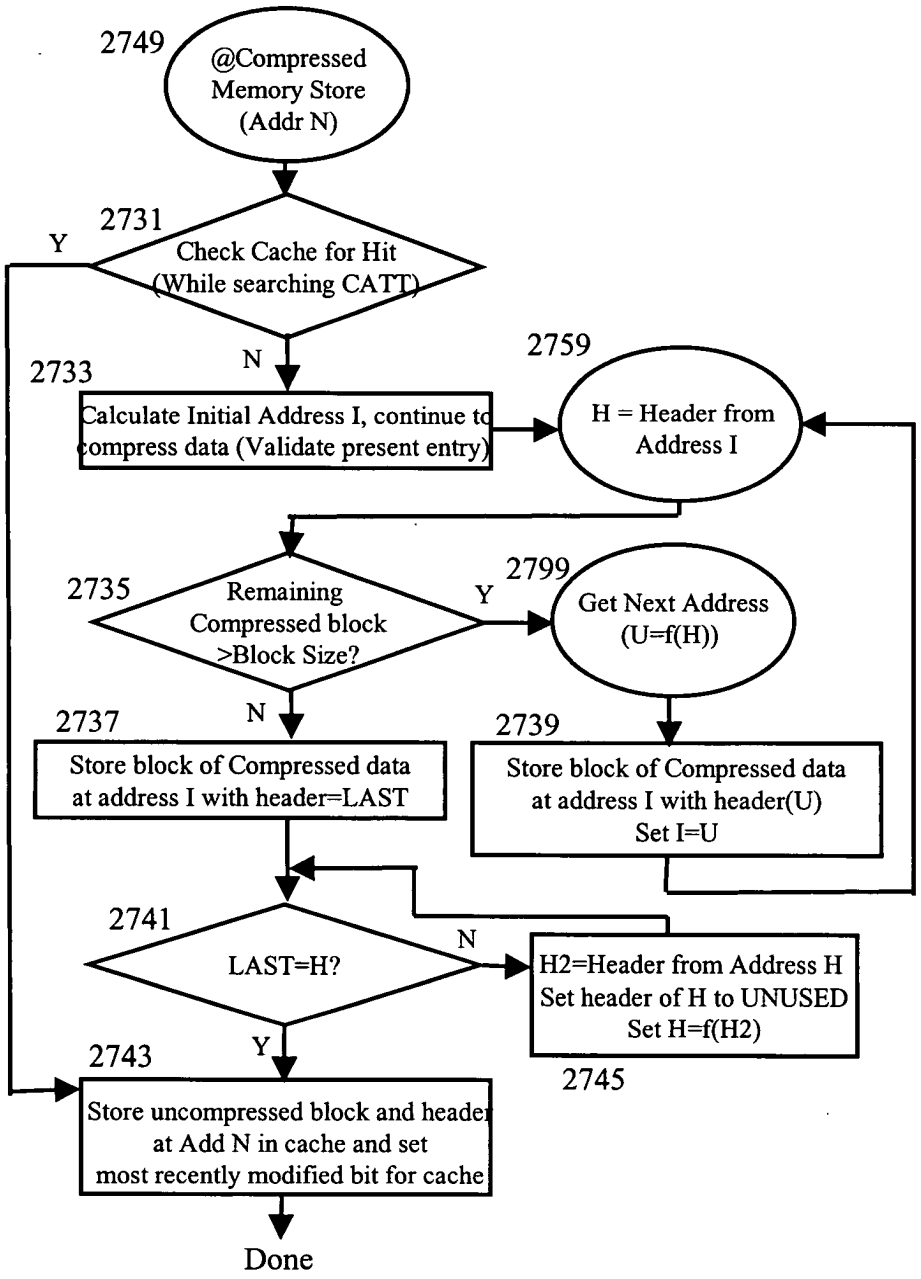


Figure 27

09239659 . 012599

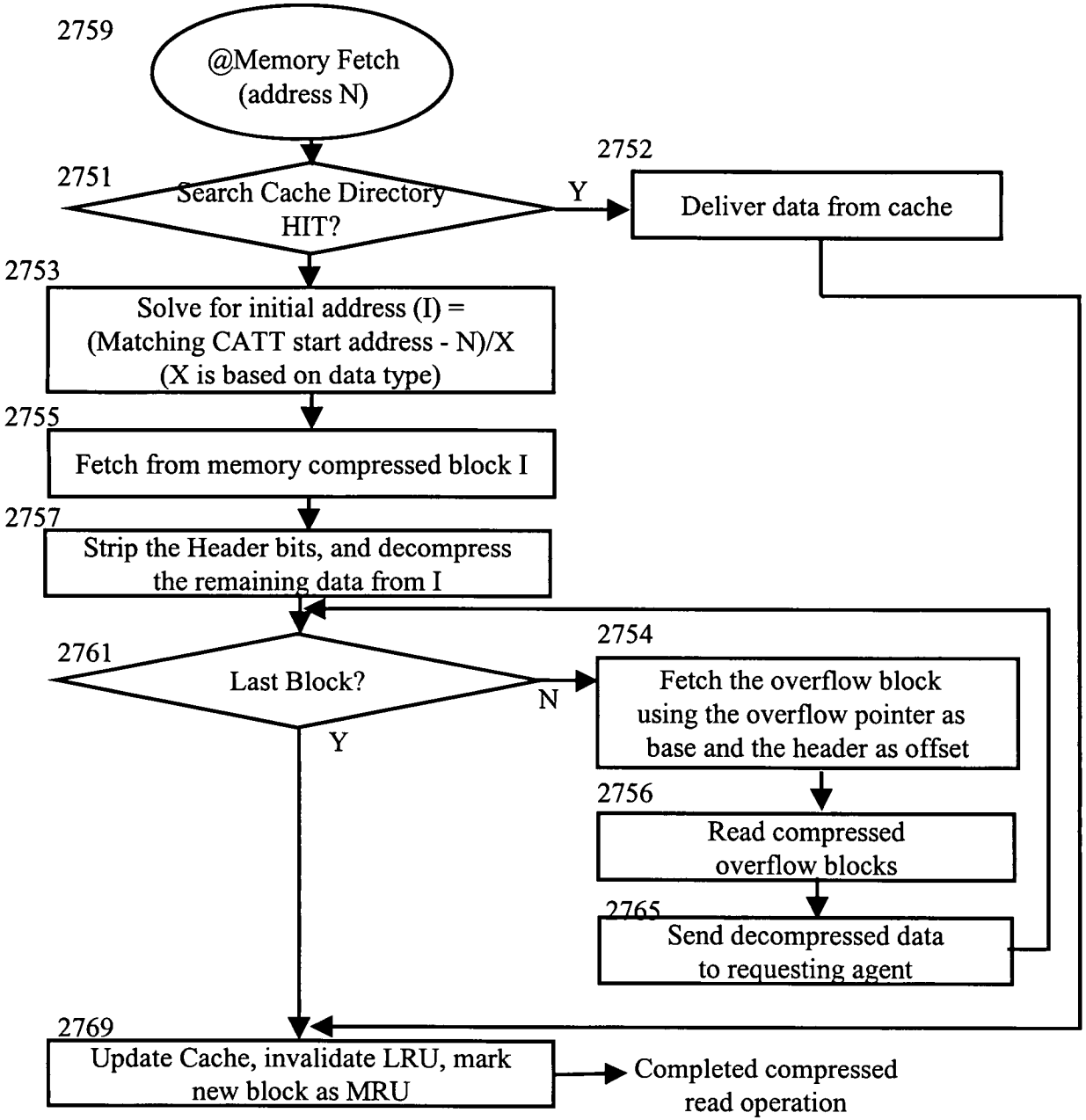

2759
@Memory Fetch
(address N)
2751
Search Cache Directory
HIT?
Y
2752
Deliver data from cache
2753
Solve for initial address (I) =
(Matching CATT start address - N)/X
(X is based on data type)
2755
Fetch from memory compressed block I
2757
Strip the Header bits, and decompress
the remaining data from I
2761
Last Block?
N
Y
2754
Fetch the overflow block
using the overflow pointer as
base and the header as offset
2756
Read compressed
overflow blocks
2765
Send decompressed data
to requesting agent
2769
Update Cache, invalidate LRU, mark
new block as MRU
Completed compressed
read operation

Figure 28

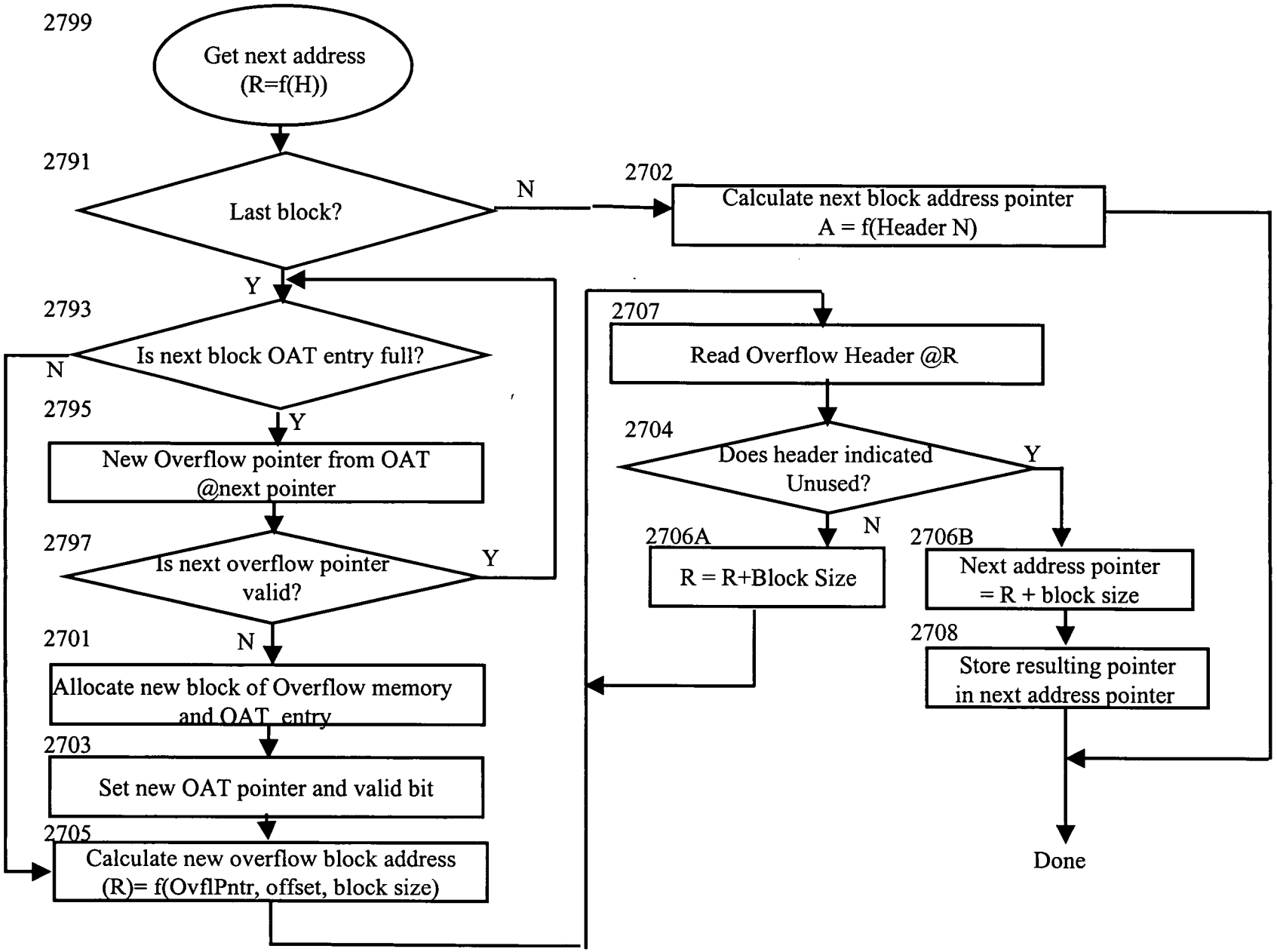
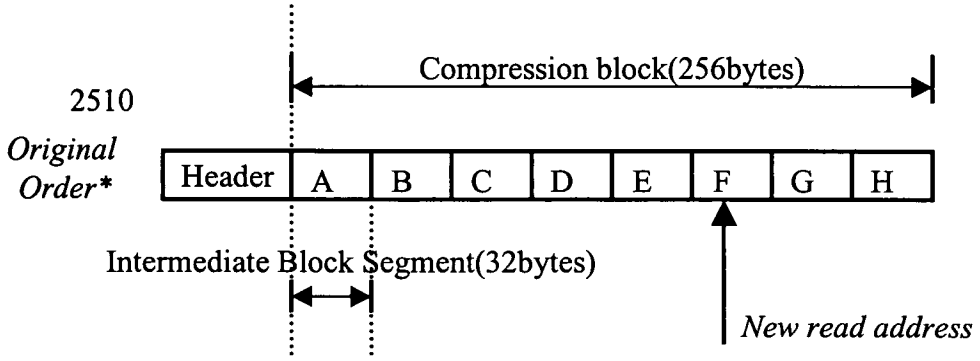

2799
Get next address (R=f(H))
2791
Last block?
N
2702
Calculate next block address pointer A = f(Header N)
Y
2793
Is next block OAT entry full?
N
Y
2795
New Overflow pointer from OAT @next pointer
2797
Is next overflow pointer valid?
Y
N
2701
Allocate new block of Overflow memory and OAT entry
2703
Set new OAT pointer and valid bit
2705
Calculate new overflow block address (R)= f(OvflPntr, offset, block size)
2707
Read Overflow Header @R
2704
Does header indicated Unused?
Y
N
2706A
R = R+Block Size
2706B
Next address pointer = R + block size
2708
Store resulting pointer in next address pointer
Done

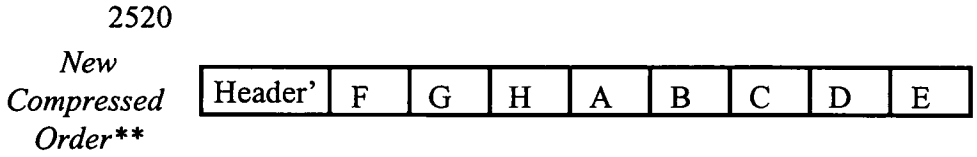
Figure 29

Uncomp Block Bytes	Type	Initial Block Size Bytes	Overflow Block Size Bytes	Max Comp Ratio (X:1)	Initial Allocation	Header w/o OF	Header w/ OF Non-Frag	Header w/ OF Fragmented
4096	8	256	64	16	6%	0.0%	0.4%	4.1%
2048	7	128	64	16	6%	0.1%	0.5%	4.2%
1024	6	64	64	16	6%	0.2%	0.6%	4.3%
512	5	64	64	8	13%	0.2%	0.9%	4.3%
256	4	64	64	4	25%	0.2%	1.4%	4.3%
128	3	32	32	4	25%	0.4%	2.8%	8.8%
64	2	32	16	2	50%	0.4%	5.1%	13.6%
32	1	32	8	1	100%	0.4%	8.9%	11.5%

Figure 30



* Header tag field is '0' indicating in original order



** Header tag field is '5' indicating out of order

2530

1) Read compressed block from memory
2) Decompress to L3 data cache
3) Store Position tag (@F) in table
4) Re-compress block out of order
5) Attach header with tag (@F)
6) Write compressed block back to memory

Figure 31

Bytes Compressed	Flag	Index	Count	Data	**Bits Used**
0	0	-	-	8b	9
1	10	6b	-	-	8
2	1100	6b	-	-	10
3	1101	6b	-	-	10
4	1110	6b	-	-	10
5	1111000	6b	-	-	13
6	1111001	6b	-	-	13
7	1111010	6b	-	-	13
8	1111011	6b	-	-	13
9	1111100	6b	-	-	13
10	1111101	6b	-	-	13
11	1111110	6b	-	-	13
>11	1111111	6b	12b	-	25

Figure 32

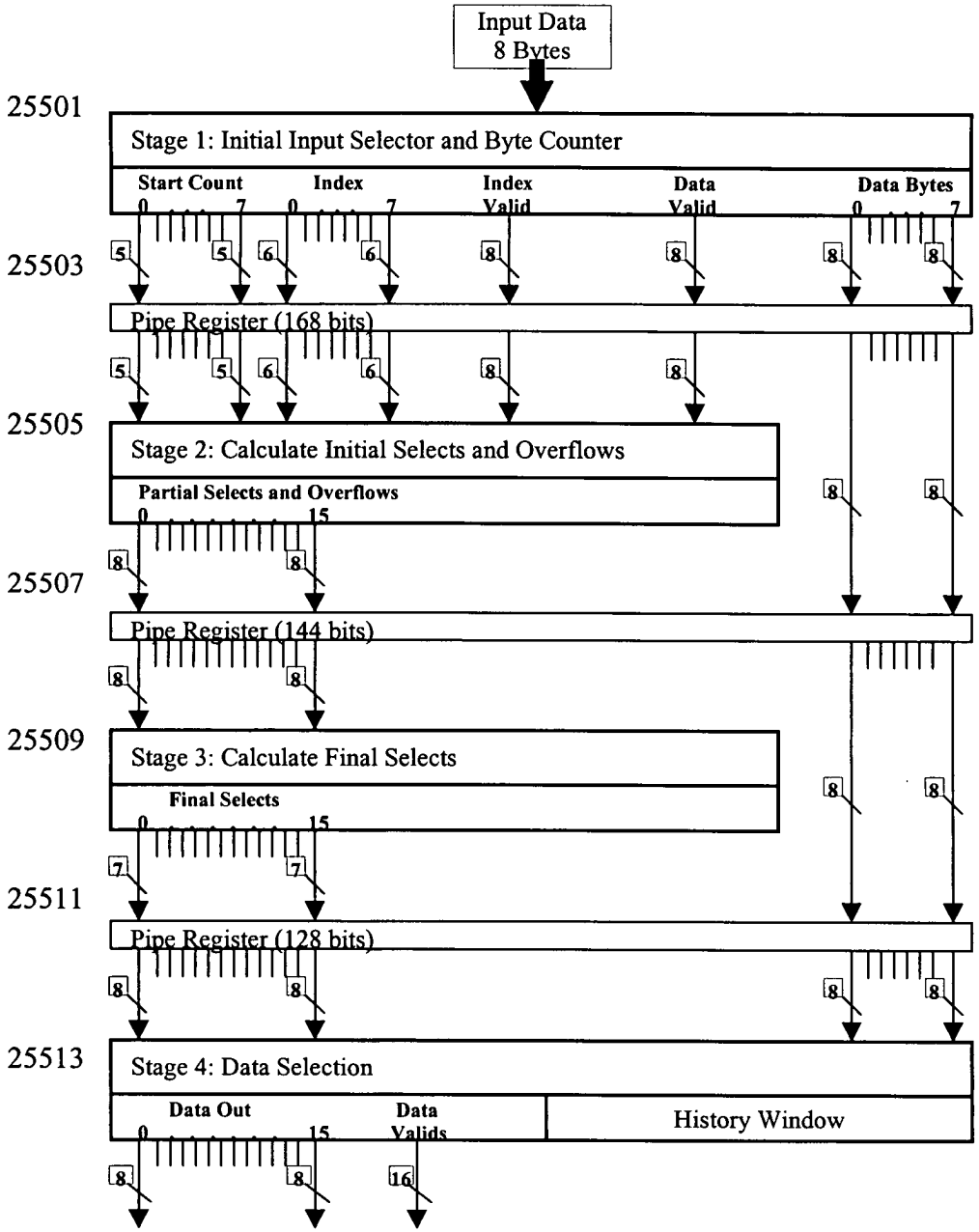

Input Data
8 Bytes
25501
Stage 1: Initial Input Selector and Byte Counter
Start Count
Index
Index Valid
Data Valid
Data Bytes
25503
Pipe Register (168 bits)
25505
Stage 2: Calculate Initial Selects and Overflows
Partial Selects and Overflows
25507
Pipe Register (144 bits)
25509
Stage 3: Calculate Final Selects
Final Selects
25511
Pipe Register (128 bits)
25513
Stage 4: Data Selection
Data Out
Data Valids
History Window

Figure 33

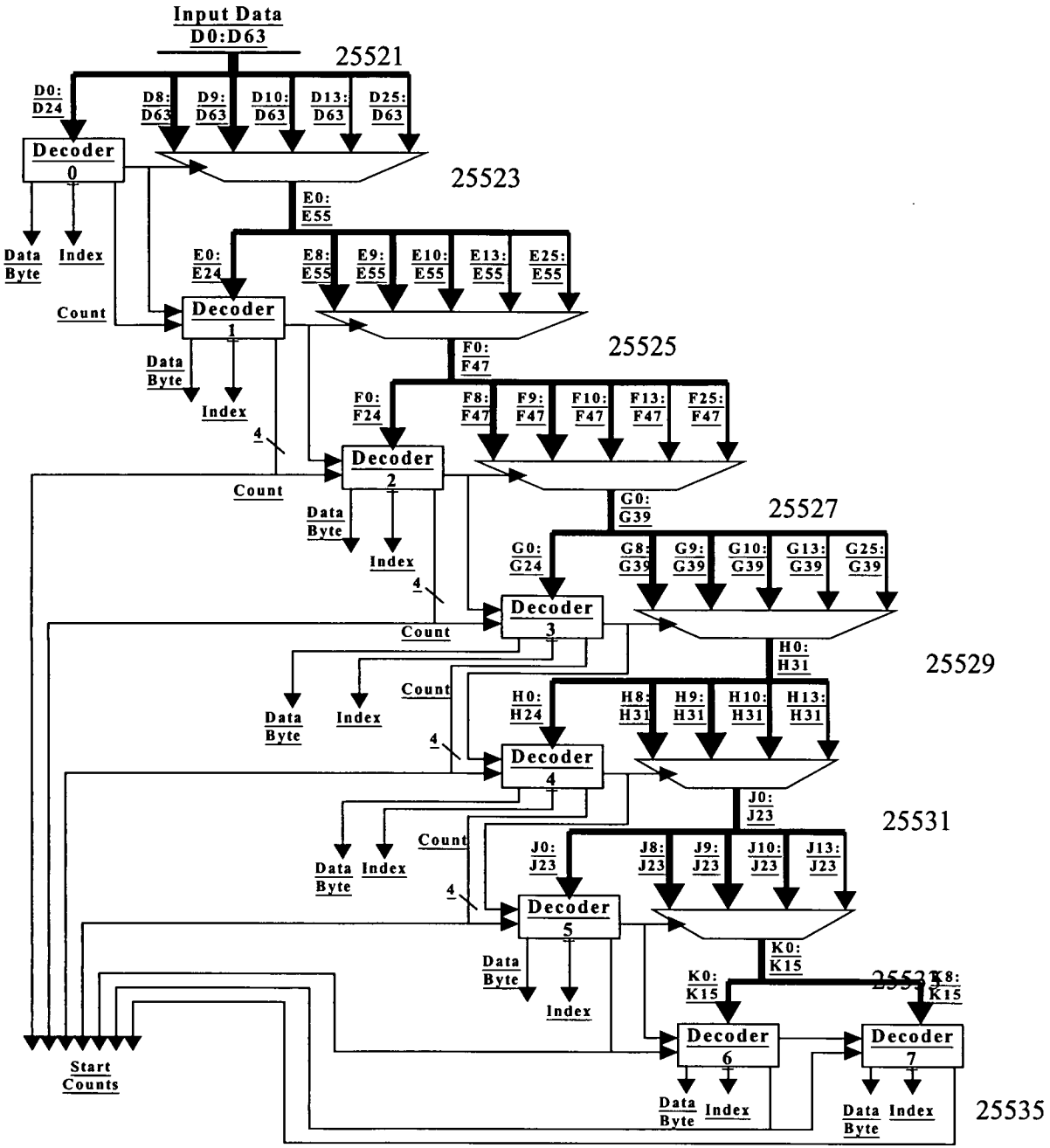

Input Data
D0:D63
25521
D0: D24
D8: D63
D9: D63
D10: D63
D13: D63
D25: D63
Decoder 0
25523
E0: E55
Data Byte
Index
E0: E24
E8: E55
E9: E55
E10: E55
E13: E55
E25: E55
Count
Decoder 1
25525
F0: F47
Data Byte
Index
F0: F24
F8: F47
F9: F47
F10: F47
F13: F47
F25: F47
4
Decoder 2
Count
25527
G0: G39
Data Byte
Index
G0: G24
G8: G39
G9: G39
G10: G39
G13: G39
G25: G39
4
Decoder 3
Count
H0: H31
25529
Data Byte
Index
H0: H24
H8: H31
H9: H31
H10: H31
H13: H31
4
Decoder 4
Count
J0: J23
25531
Data Byte
Index
J0: J23
J8: J23
J9: J23
J10: J23
J13: J23
4
Decoder 5
K0: K15
Data Byte
Index
K0: K15
K8: K15
Decoder 6
Decoder 7
Start Counts
Data Byte
Index
Data Byte
Index
25535

Figure 34

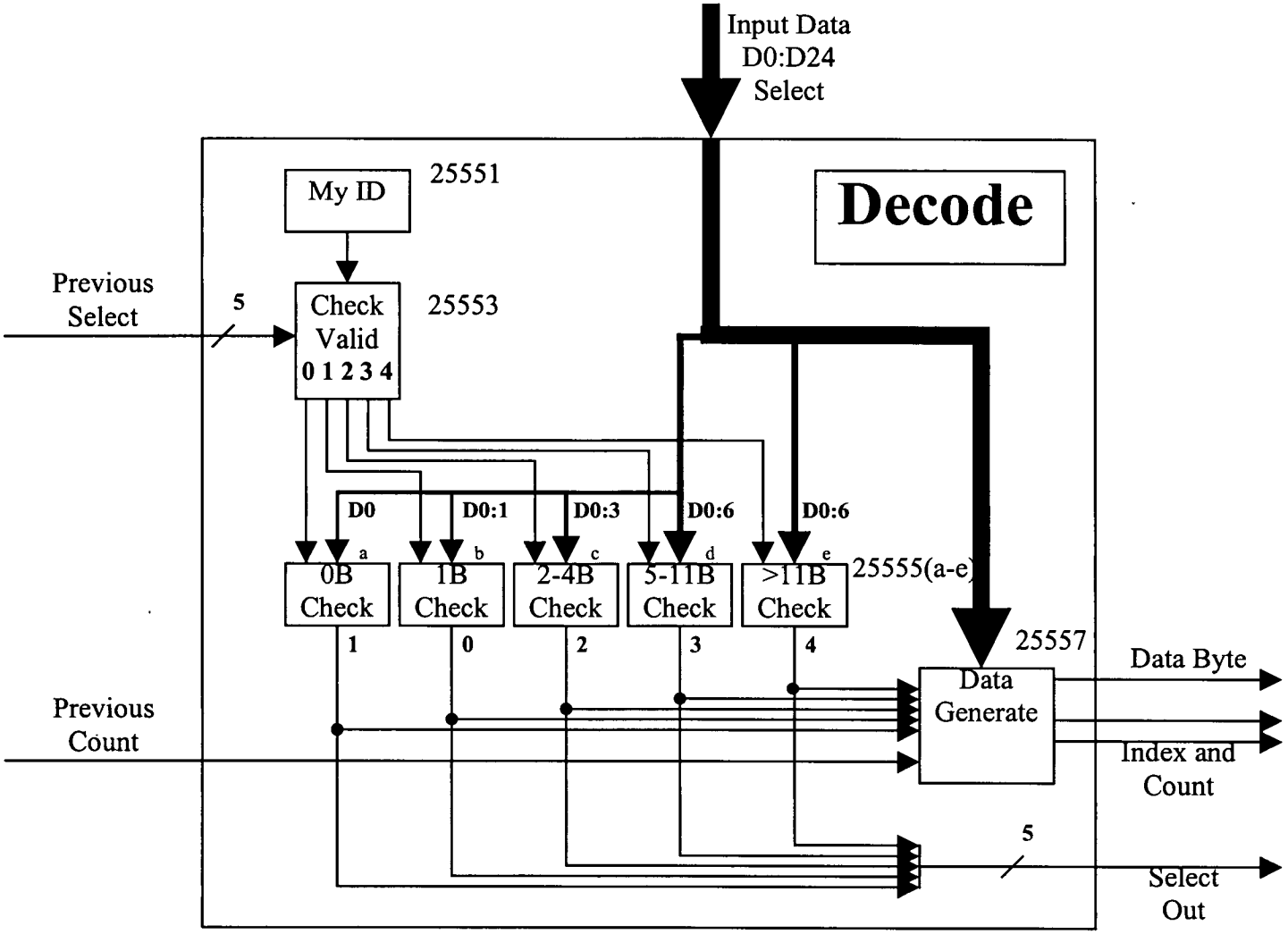

Input Data
D0:D24
Select
Decode
My ID
25551
Previous
Select
5
Check
Valid
0 1 2 3 4
25553
D0
D0:1
D0:3
D0:6
D0:6
a
b
c
d
e
0B
Check
1B
Check
2-4B
Check
5-11B
Check
>11B
Check
25555(a-e)
1
0
2
3
4
25557
Data
Generate
Data Byte
Previous
Count
Index and
Count
5
Select
Out

Figure 35

Previous Select	10	08	04	02	01	00
My ID=01	1F	1F	1F	1F	1F	00
My ID=02	1F	1F	1F	1F	1F	00
My ID=04	1F	1F	1F	1F	1F	00
My ID=08	1F	1F	1F	1F	1E	00
My ID=10	1F	1F	1F	1F	1E	00
My ID=20	1E	1E	1E	1E	00	00
My ID=40	1E	1E	1E	1C	00	00
My ID=80	08	00	00	00	00	00

Figure 36a

Select	10	08	04	02	01	00
Data Byte	X	D1:D8	X	X	X	X
Index	D2:D7	X	D4:D9	D7:D12	D7:D12	X
Count	PC+1	PC+1	D2:D3+PC+2	D4:D6+PC+5	D13:D24+PC	X

Figure 36b